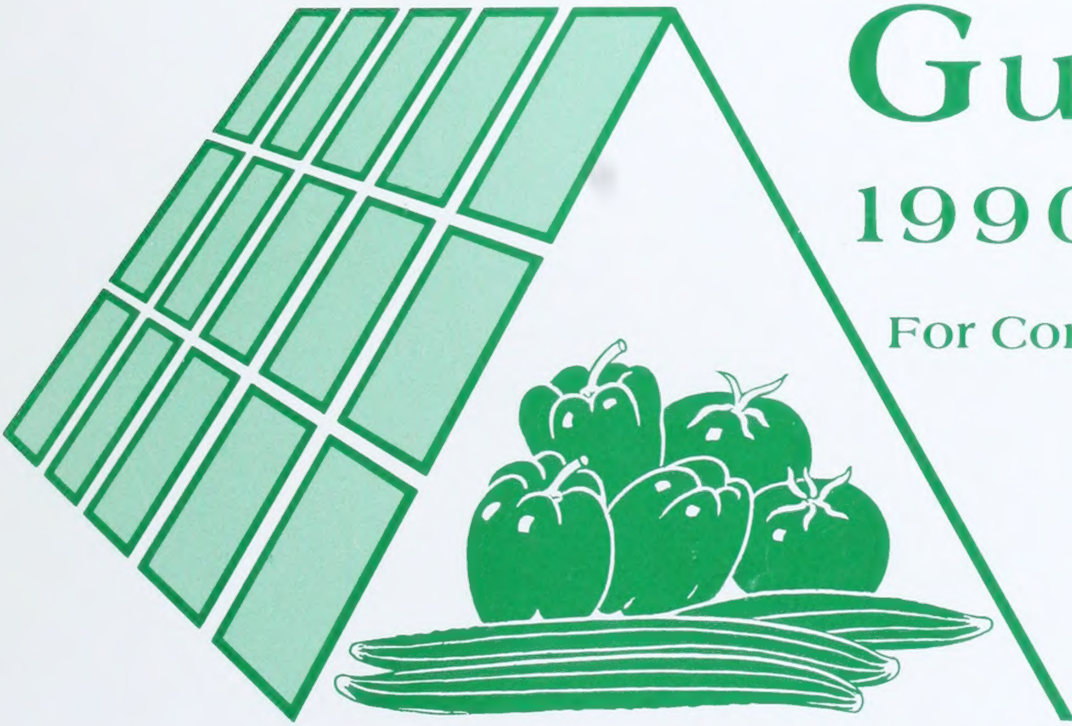
Greenhouse Vegetable Production Guide

1990 - 91

For Commercial Growers



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Greenhouse Vegetable Production Guide

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ACKNOWLEDGEMENTS

The Commercial Greenhouse Vegetable Production Guide is a combination of production information on seedless cucumbers, tomatoes and peppers. The information is based on the experience gained at the Alberta Special Crops and Horticultural Research Center, Brooks and the Alberta Tree Nursery and Horticulture Centre, Edmonton. Information has also been utilized from the Vegetable Production Guides of British Columbia and Ontario.

My special thanks to staff of Alberta Agriculture, especially Dr. Ron Howard for his input into the 'Disease' section and other useful suggestions.

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Greenhouse Crops Specialist

January, 1990

INTRODUCTION

Growing plants out of season when outdoor conditions are unsuitable is the basic reason for growing crops in protected environments, and that is the reason for building greenhouses. Primary considerations are satisfactory plant growth and economics. Natural light conditions will affect plant growth and are the single most important factor that should be taken into account before deciding on the kind of vegetables to be grown.

The province of Alberta stretches from 49° north to 60° north and the winter light conditions vary from south to north. Light is a critical and a limiting factor for the production of greenhouse vegetables during winter, but during summer there is an overabundance of light. Consequently shading is required. A comparison of solar radiation at Suffield, located just above 50° north, and Edmonton located 53° north shows that Suffield gets 13.0% more light annually than Edmonton. A further comparison of solar radiation for various seasons indicates that Suffield gets 28.0%; 12.0%; 18.0% and 33.0% better light respectively for the winter period, spring period, summer period and fall period.

This means that during the period of most limiting light, the differential between Suffield and Edmonton is high in terms of both hours of sunshine and available solar energy. Conversely, in spring and summer, when plant growth is least limited by light, the differences between Suffield and Edmonton are reduced but still significant. Adjustments in planting schedules are therefore necessary. Schedules are suggested for various areas in Alberta in appropriate sections.

GREENHOUSE ENVIRONMENT

A greenhouse is a structure designed to control the conditions surrounding plants. These conditions include the light falling on the leaves, the temperature and moisture of both soil and air, the nutrient elements available and the diseases and insects that attack the plants. Factors such as heat, water, nutrients and diseases can be controlled, but nothing can be done to control light. Artificial light can seldom be added profitably because of cost.

The Effect of Temperature

The temperature of a plant regulates the rate at which all the growth processes proceed. Each plant has an optimum temperature for growth, which varies from crop to crop. For example 12 to 15°C is highly favorable for the growth of lettuce, but too low for cucumbers.

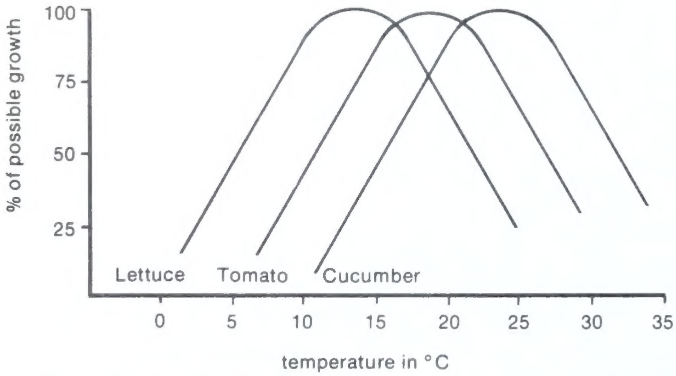

Figure 1. Idealized growth curves for several crops with changing temperature

Figure 1 is a diagrammatic illustration of the growth curves of several crops. These growth curves are idealized, but they demonstrate that a temperature favorable to one crop may be entirely unsatisfactory for another.

The temperature in a greenhouse must not fluctuate too widely from the optimum or growth will be reduced. Also, with rapid temperature changes there is danger of condensation on the leaves and an increase in leaf diseases. A living plant constantly uses food in its respiration. The rate at which food is consumed rises with temperature. Figure 2 shows the type of curve obtained with most plants.

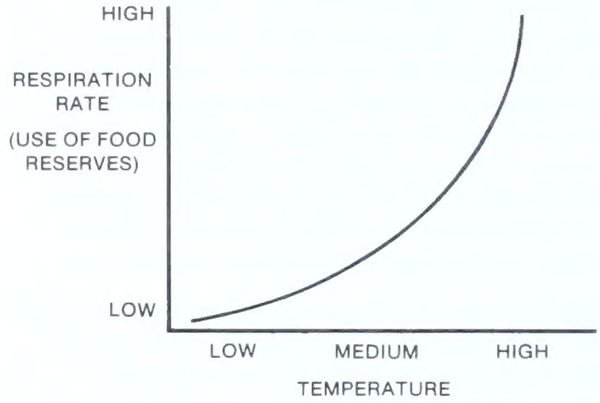

Figure 2. The effect of temperature on respiration rate

Lowering the temperature conserves the food reserves in the plant.

A green plant while in the light is using food but at the same time is producing new food through the process called photosynthesis. The speed at which food production goes on is also controlled by temperature. However, the type of curve is different, as show in figure 3.

Since no food is produced at night the temperature should be lowered somewhat. In this way the food produced during the day is conserved by reducing night time respiration. If temperatures are kept high at night or during dull weather, spindly, soft plants result. Lowering the night temperature benefits the crop and results in a considerable fuel saving.

The respiration and photosynthesis curves vary somewhat for different plants, but the general

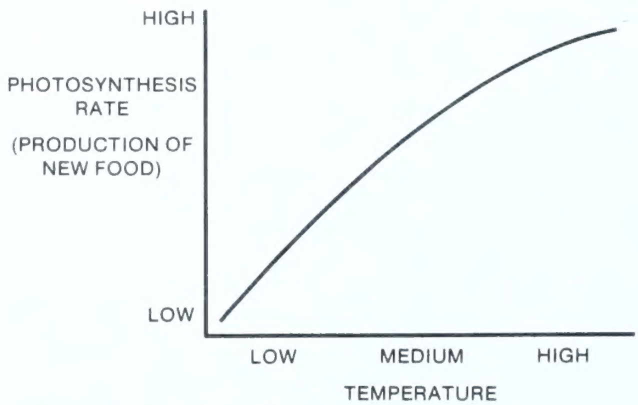

Figure 3. The effect of temperature on photosynthesis rate

pattern is the same for all species. In each case at a low temperature only a small amount of new food is produced, and only a small amount consumed, leaving little or no surplus. At medium temperatures (corresponding to optimum temperature for the several crops in figure 1), photosynthesis has increased sharply but respiration only sightly. This means that more food is produced than consumed and a reserve is built up. At high temperatures, respiration rises rapidly and soon cancels out the high rate of photosynthesis.

Where does the heat come from? The energy from sunlight shining through a greenhouse is trapped inside the house and becomes heat. During bright days a very large amount of heat is derived from sunlight, and getting rid of excess heat often becomes a real problem. Even during the shorter and duller days of winter a substantial part of our daytime heating is done by the sun.

Artificial heat must be supplied to the greenhouse especially at night. Heat must be moved from a source (coal, oil, or gas boiler) to the air and soil around the plants. The most common heating system is a gas-fired steam boiler with pipes carrying the steam along the outer walls and above or among the plants. Air moves over the pipes carring heat upwards with it and then among the plants. Many different pipe layouts are used to improve heat distribution. In very wide houses, pipes may be led along the house near the ground and away from the walls. Sometimes a portion of the heating pipe is placed above the crop and a few greenhouses are equipped with electric fans to circulate the air and to speed up the heating process. Any system may be used which will heat the whole house uniformly, the choice of a particular system depends on economic and engineering difficulties.

Where does the heat go? Most of the heat loss occurs directly through the walls and glass of the greenhouse. The greater the difference between outside and inside temperatures, the more rapid will be this type of heat loss. In addition to the heat lost by direct conduction, there is a large amount of heat carried out of the greenhouse by the air leaving the ventilators. In order to control the greenhouse humidity, ventilation is necessary almost every day. As the air moves through the greenhouse it picks up heat and water and carries both of them away.

Temperature control. To control temperature, it is absolutely essential to have a thermometer in each house. The thermometer should be placed at plant level and should be moved as the plants grow. At planting time, the thermometer should be hung about 0.3 metres above ground. As the plants become taller, it should be raised until it is at eye level. Temperatures often vary in different parts of the house. For example, when steam or hot water is passing through the heating pipes, the plants near the pipes will be warmer than in the centre of the house. When the pipes are cold, plants near the wall may be colder than those in the centre. Many houses also have cold spots that tend to be several degrees cooler than other parts of the house.

Automatic temperature controls are fairly expensive to install but they relieve the operator of much work and are always on the job. If automatic controls are not used, the operator must check the thermometer frequently. It is impossible to feel the temperature of a house accurately, so do not depend on how the air feels.

Whether the temperature control is automatic or manual, there are still two alternative methods of control: the operator may change the amount of ventilation, or he may change the amount of heat being supplied to the house. To reduce humidity some ventilation is necessary, even during the coldest weather. A good rule is to consider the ventilation needs of the crop first and then add heat to maintain the necessary temperature.

Supplemental Carbon Dioxide

Normal air contains about 300 parts per million (ppm) of carbon dioxide (CO_2). In a greenhouse, carbon dioxide levels rise during the night owing to its release by the plants and by soil organic matter. During the day, if the greenhouse is kept closed, carbon dioxide is rapidly depleted and may often be below 200 ppm on fairly bright days. This is the point at which carbon dioxide addition is most important, however, research has shown that greenhouse crops will almost always be improved if carbon dioxide levels are raised up to 1000 to 1500 ppm. The level to which the carbon dioxide concentration should be raised is dependent on the crop, light intensity, temperature and growth stage of the crop. Carbon dioxide is taken up by the plant through pores in the leaves. These pores will close if the plant is under water stress or if temperatures are excessive. Addition of carbon

dioxide under either of these conditions is of no benefit since photosynthesis occurs only during daylight hours; carbon dioxide addition is not required at night. Supplementation should start approximately one hour before sunrise and the system should be shut off one hour before sunset.

When ventilators are opened, it is not possible to maintain high carbon dioxide levels. Research at the Alberta Tree Nursery and Horticulture Centre, Edmonton has indicated that if alternate methods of cooling can be used e.g. fogging or a pad and fan, then a higher CO_2 level (1000-1500 ppm) is very beneficial to plants. Substantially higher yields can be obtained by using additional CO_2 and by maintaining adequate temperature during day time.

PRODUCTION INFORMATION

Management

Greenhouse management involves:

- a maintenance program (electrical/mechanical)
- sanitation and sterilization practices
- proper crop scheduling
- seedling health care
- transplanting
- nutrient/fertilizer preparation
- analysis of growing media at regular intervals
- crop maintenance – pollinating, pruning, training and harvesting
- pesticide scheduling/application
- packaging and marketing
- personnel management
- timely trouble shooting

For successful culture, a grower must understand the above mentioned management aspects. Timely trouble shooting is important. Assistance in diagnosing problems can be obtained by contacting the greenhouse crops specialists at the Alberta Special Crops and Horticultural Research Centre, Brooks, or Alberta Tree Nursery and Horticulture Centre, Edmonton.

Greenhouse Soil Management

Type and Condition of Soil

Most of the greenhouse vegetable crops in Alberta are grown in soil. Because of disease problems, growers are switching over to alternate methods, such as containers with soilless media, rockwool, sawdust and Nutrient Film Technique. These alternate methods require higher inputs in terms of water and fertilizer management.

The main purpose of the soil is to provide a medium in which there is a proper balance between air, water and nutrients. If this balance exists the roots will easily obtain their requirements of water and nutrients and growth will be rapid.

A greenhouse soil should be a sandy loam with a high organic matter content if at all possible. A fine textured or heavy soil tends to compact easily. It also stays wet during long periods of cloudy weather. In contrast, in a sandy soil, both air and water move freely and compaction is slight, so roots can grow through the soil more easily.

Any soil, either in the greenhouse or in the field before being brought into the greenhouse, can be improved by adding organic matter. It should be kept in mind that the organic matter is being added as a soil conditioner primarily and not so much for its nutrient value. It takes several years to change the condition of a soil and the addition of organic matter to the soil should be a continuing process.

Soil Testing

Before planting greenhouse vegetable crops, it is advisable to have the soil tested in order that nutrient levels can be adjusted to the required levels. After planting, soil tests should be done at regular intervals.

How should a soil sample be taken? Because only a small amount of soil is required for testing, it is important that the sample truly represent the composition of all the soil in the area to be tested. To ensure this, take a number of samples from several areas of each house and bulk them. Then mix these sub-samples and take out the amount to be sent away. If the area is large and different soil textures are encountered, several samples should be sent. Samples should be taken at depths of 15 to 30 cm. It is preferable to dry them overnight before shipping. The final sample sent in for analysis should weigh from 200 to 500 g after drying.

When should a soil test be done? A test should be done immediately after a crop is removed. The results of this test will determine the nature and quantity of preplant fertilizers or manure to be used. A second test should be done two to three weeks before planting and after soil sterilization (steam or chemicals) has been done. In the case of cucumber, a weekly soil test should be done for the first four weeks and on a monthly basis thereafter. Fertilizer schedules should be modified accordingly. A soil sample should also be taken whenever a fertility problem is suspected in a greenhouse. It usually takes about one week to get results back to the grower from the Soils and Animal Nutrition Laboratory. Private laboratories may provide results quicker.

How and where should a soil sample be sent? Sample boxes are available from your local district extension office. Complete the green information sheet to facilitate fertilizer recommendations. Samples can be mailed through your district extension office or directly to the Soil and Animal Nutrition Laboratory, O.S. Longman Building, 6909 - 116 Street, Edmonton, Alberta T6H 4P2. Greenhouse soil samples receive priority and are analyzed in a different manner from field samples. It is very important, therefore, to identify them by completing the greenhouse soil information sheet and labelling the containers as greenhouse soil samples, especially if they are sent under separate cover. Ensure that the requested information is provided. It will help the greenhouse specialist make proper recommendations.

Private soil testing laboratories have their own containers. The addresses are given on page 66. Please contact these laboratories directly for cost and sample information.

Explanation of soil test values. Table 1 summarizes the accepted good fertility levels for most greenhouse crops. Specific recommendations for balancing nutrients, correcting pH and improving soil texture are made for each soil sample sent to the Soil and Animal Nutrition Laboratory. The recommendations are made by the greenhouse crops specialists at the Alberta Special Crops and Horticultural Research Centre, Brooks, or the Alberta Tree Nursery and Horticulture Centre, Edmonton. Because different laboratories use different extraction procedures, it is likely that recommended nutrient levels will differ between laboratories. The Soil and Animal Nutrition Laboratory uses water extraction procedures.

Soil Mixes for Seedlings

Many different composts and mixes have been tested and proposed for the growing of cucumber seedling transplants. Commercial soilless media have proven to be successful in raising healthy, uniform seedlings.

Table 1. Recommended fertility levels for a growing medium used for greenhouse vegetable production*

Ammonium nitrogen	0- 20
Nitrate nitrogen	35-180
Phosphorus	5- 50
Potassium	35-300
Calcium	60-400
Magnesium	30-200
Sodium	0- 30
Sulfates – S,	30- 60
Nitrites	nil
Chloride	nil
Free Lime	trace
pH	5.5-6.9
Electrical Conductivity (mmhos/cm^2)	0.8-3.0
Zinc	0.3-3.0
Copper	0.001-0.5
Manganese	0.02-3.0
Iron	0.3- 5.0
Boron	0.05-0.5
Molybdenum	0.01-0.1

*parts per million of water extractable nutrients

You can make your own mix as well. The following are two mixes which give good results. After you have prepared these mixes, do get them analyzed. It never hurts to know the composition of your mixture.

Soil Mix One Cubic Metre

0.59 m^3 sandy loam
0.26 m^3 peat moss
0.15 m^3 coarse silt free graded sand
0.60 kg, 20% superphosphate

If pH is below 6.0, add 1.2 kg calcitic limestone

Soilless Mix One Cubic Metre

0.55 m^3 peat
0.44 m^3 vermiculite
1.20 kg calcitic limestone
1.20 kg dolomitic limestone
0.60 kg 20% superphosphate
0.60 kg potassium nitrate with micro-nutrients
18.5 g borax

Note: 1 m^3 = 1046 L

Pre-Crop Application of Fertilizers, Straw and Manure

Application of Fertilizers

A soil test must be made before deciding on any pre-crop application of fertilizers. In general, less soluble fertilizers such as superphosphate should be incorporated. Nitrate and potassium are best applied at the time of planting.

Application of Straw

Straw is incorporated in soil to provide organic matter and to improve soil structure. Straw helps to loosen the soil and improve aeration. Wheat and barley straw are commonly used. Use ten bales/100 m^2. A bale generally weighs 18 kg. Straw should be well chopped up before incorporation. Straw can also be used as a mulch in growing beds to reduce weed development and diseases when, for instance, tomato crops are layered on the ground. Be sure that the straw is not contaminated with herbicide residues.

Decomposition of straw is a gradual process and extra nitrogen should be added to facilitate this process. If extra nitrogen is not added, the growing plants and decomposing straw will compete for available nitrogen.

Use of Manure

Well rotted manure can be incorporated as an organic amendment and also as a source of potash and other nutrients. Manures are generally very high in salts like sodium and chloride. It is, therefore, very important that manure be analyzed **before application** and another soil test taken after incorporation. If sodium and potassium are above the recommended levels, leaching is recommended. **Caution**: If the growing medium is high in salts and the water is high in sodium, then plant damage can occur as a consequence of the use of manure.

Application of Gypsum and Calcium

It is desirable to maintain adequate levels of calcium. The usual practice is to make enough of it available before planting. In soils where the calcium level is low but the pH is satisfactory, calcium sulphate (gypsum) may be used instead of calcitic limestone. Generally 75 to 25 kg/100m^2 of gypsum will be required when the test ranges are between 100 and 400 parts per million of calcium.

Soil pH and its Correction

The term pH means the degree of acidity or alkalinity of the soil or growing media. It is measured on a scale from 0 to 14 with 7 being neutral. The availability of many nutrients, especially micronutrients, is affected by the pH of the growing media. Cucumber, pepper and lettuce plants grow best at pH 6.0-7.0. In soilless mixes the pH range is between 5.5 to 6.5.

The safest way to reduce pH is the pre-plant incorporation of acidic peat moss in growing beds. Incorporate peat moss in the top 10 to 15 cm of beds. Besides reducing pH, peat moss application will help in the dilution of higher soluble salts.

Other pre-crop treatments to reduce alkaline pH are:

1. Finely ground sulphur — 4 kg/100 m^2
2. Aluminum sulphate — 5 kg/100 m^2
3. Iron sulphate — 5 kg/100 m^2

Table 2. Suggested pre-crop fertilizers

Fertilizer	Major nutrients supplied	Effect on pH	Approximate rate
Superphosphate 0-20-0	Phosphorus Calcium Sulphur	No change	25 kg/100 m^2
Gypsum*	Calcium Sulphur	No change	25 kg/100 m^2
Potassium sulfate 0-0-50	Potassium Sulphur	No change	10 kg/100 m^2
Ground limestone*	Calcium	Alkaline	25 kg/100 m^2
Dolomite limestone*	Calcium Magnesium	Alkaline (slow acting)	25 kg/100 m^2

* Use exact rates as determined by a soil test

The application rates will reduce the pH by approximately one unit. Ground sulphur is the most commonly used. Its effect on pH becomes evident three to four months after application and generally will last for one to two years.

When the growing medium is acidic such as in prepared mixes, lime application is required. Use table 3 as a guide for applying lime.

The above recommendations are made in terms of ground limestone. Dolomite limestone may be substituted at par.

It is advisable that growers conduct their own lime requirement test and allow for reaction time. Such a test can be conducted by analytical laboratories.

Incorporating limestone into the soil does not change the pH immediately. The pH of some greenhouse soils may rise slowly for weeks after such an application. In some areas of the soil, the pH will change as soon as the limestone becomes moist. Hence, the root may pass through zones differing widely in pH, absorbing the desired available nutrients from each zone.

Hydrated lime generally should not be used in greenhouse soil. It is much more reactive than limestone. Ammonium nitrogen is absorbed on the soil complex and hydrated lime may displace it in quantities sufficient to damage roots. Hydrated lime also increases soluble salts, often to dangerous levels. Furthermore, the rapid change in soil pH is seldom desirable. In the few instances where a crop is detected growing in an extremely acid medium, hydrated lime may be suspended in water at 1 kg/45 L and applied at 200 L/100 m^2. This should be followed by an application of limestone to further correct the pH, assuming that the hydrated lime will have raised the pH by 0.5 units.

Sphagnum peat moss is widely used in preparing various growing media. Its pH may vary from 3.0 to 4.5. As a general rule, 4 kg of dolomite limestone should be used for each cubic metre of peat as it comes from the bale. If the pH of the peat is below 4.0, increase limestone to 5-6 kg/m^3.

Adjustment of Soil pH in a Standing Crop

An alkaline pH may result during crop growth because of the continued use of basic fertilizers such as calcium nitrate (15.5-0-0). Phosphoric acid or sulphuric acid at 3-6 ml/100 L of water should correct this problem. If a constant feed program is followed, use a double head injector to feed acid separately. Never mix fertilizers with acids because precipitation will occur. If a weekly feeding program is followed, use acidified water between feedings.

The soil pH can also be controlled during cropping by using acidic fertilizers. Refer to the section on fertilizer management. Consult the section on water quality. Potassium bicarbonate can be used to bring the pH to normal levels, when peat-based media show an acidic pH. Use a 50 g/100 L rate until the pH rises to the desired ranges.

Soilless Culture

Cucumbers can be successfully grown in inert media such as peat, peat + vermiculite, peat + perlite, sawdust, bark chips, sand, etc. Such media require more detailed pre-crop preparations than soil. Good results are obtained by adding limited amounts of fertilizers.

The formula for one mix which can be used for satisfactory crop production is found in table 4. Such a mix can be used more than once and can be steamed to eliminate pathogen infestations if necessary.

Table 3. Pre-plant lime application for pH adjustment to 7.0 (neutral) for different soil textures

Soil pH reading	Sands –	Loams – silty Clay – loams	Clay – loams – clay	Organic
	Kilograms of ground limestone required per 100 m^2			
4.0	—	—	—	500
4.5	—	—	—	450
5.0	—	—	—	350
5.6	62.5	100	250	300
6.0	50.0	75	200	250
6.4	30.0	50	150	175
6.8	10.0	20	50	75

Table 4. Peat-vermiculite mix (1 cubic metre)

Peat (sphagnum)	0.49 m
Horticultural vermiculite	0.49 m
Dolomite limestone	4.00 kg
Superphosphate (0-20-0)	1.20 kg
Potassium nitrate (13-0-44)	0.90 kg
Chelated iron	37 g
Borax (sodium borate)	37 g
Fritted trace elements	110 g

Fluff the baled peat before mixing. Mix very thoroughly. Calcite limestone can be used instead of dolomite, but then add magnesium sulfate at 3.0 kg per m^3.

The cucumber crop may be grown for three to four weeks on this mixture without feeding. After that period, the constant feeding program suggested in the fertilizer section should be followed. Adjustments based on regular tissues analyses should be made.

Greenhouse Sanitation

Proper sanitation is very important in controlling various diseases and pests in a greenhouse. Remove crops promptly from the greenhouse at the end of the cropping season. If plants are left to decay, pest and disease levels may build up and survive until the next crop goes in. If pests or diseases are at a high level, it may be advantageous to fumigate the greenhouse with the plants in place to prevent the dispersal of pests during the removal of crop material from the greenhouse.

Between successive crops, spray the greenhouse interior, walkways, training wires, gutters and tools with household bleach at a rate of 5 L/100 L of water or with commercially available formaldehyde at a rate of 2.5 L/100 L of water. Formaldehyde can be used as soil and space fumigant as well, when mixed with potassium permanganate. Be sure the formaldehyde is at room temperature. The formaldehyde is placed in heat resistant containers, (no more than 1 L to a 9 L container) add 188 g of potassium permanganate to treat 56 m^3 of greenhouse space.

Be careful when adding the permanganate because the reaction may be violent. Use a gas mask with a full face plate and a portable respirator is recommended during the start of the procedure. Keep the greenhouse closed for 24 to 48 hours.
Ventilate well before re-entry.

Weeds in the greenhouse and in the surrounding area are a continuous source of mite, aphid, whitefly and thrip infestation. Use a contact weedkiller such as Gramoxone (paraquat) to kill outside weeds. Proper sterilization of greenhouse soil should reduce or eliminate weed problems from the greenhouse. Remember that most of the soil sterilizing chemicals will destroy germinating weed seeds only.

Soil Sterilization

To prevent severe losses caused by soil borne diseases and nematodes, it is necessary to destroy as many of the causal organisms as possible by steaming or fumigating the soil between crops. Steam, if properly applied, will kill all living organisms in the soil and is still the most effective means of sterilization. However, with increasing fuel costs, chemical fumigation may be more attractive.

The following rules must be followed to achieve satisfactory results:

- The soil temperature at 15 cm depth must be 13°C or higher for successful treatment with chemicals.
- Soil must be in a loose condition so that penetration is complete. Sods, lumps and organic materials must be thoroughly broken up.
- If organic materials (compost, manure, etc.) are to be used, they must be incorporated before treatment so that recontamination does not occur.
- If straw is added, it must be well chopped and well decomposed before chemical fumigation.
- The soil must be moist, but not wet.

When soil is sterilized with steam or fumigated with chemicals, the number of soil micro-organisms is greatly reduced for the first few days, then it rises and eventually exceeds that of untreated soil. The first organisms to return after treatment meet no severe competition. Thus, if plant pathogens are among the first to recolonize the soil, they may develop rapidly and cause severe diseases losses. It is, therefore, important that every effort is made to prevent disease organisms from gaining entrance to the soil. Pathogens can gain entrance to the soil by

– splashing water;

– infested cuttings;

– soil in waterhose;

– infested containers;

– infested tools and equipment;

– grower's hands and foot wear;

– placing containers on ground;

– unsterilized covers;

– infected plants or seeds.

The wilt causing fungus *Fusarium oxysporum* can re-establish itself from spores in the air.

Soil Steaming

Use steam at a pressure of 48-83 kPa. It is important to maintain a soil temperature of not less than 80°C for 30 minutes throughout the soil, or in ground beds to a depth of 36 cm. Use an accurate thermometer. It may require four to eight hours to establish this level of uniform temperature depending upon the soil texture. The most commonly used method of steaming is to cover the beds with a tarp and release steam inside. The penetration of steam is not very good. The best method is to apply steam through a network of drain tiles. Such tiles should be laid approximately 60 cm deep, at 60 cm intervals with a 5 cm layer of gravel at the top. Steaming through drain tiles can achieve good penetration to control nematodes.

Particular care must be taken to adequately heat the soil adjacent to footings of walls, support poles and other underground structures. Escape of steam through blowholes in very loose, dry soil, e.g., near heating pipes, should be prevented.

Avoid over-steaming. Try to ensure that the temperature does not exceed 95°C in any portion of the treated area. Undesirable effects of oversteaming include:

– excessive ammonia release;

– manganese toxicity;

– increased total salts; and

– destruction of organic matter.

Leaching is usually required after steaming. Do not use ammonium fertilizers for at least two months after steaming because of the small populations of nitrifying bacteria that can convert ammonium to nitrate nitrogen.

Soil Fumigation

Some fumigants control fungi, bacteria, nematodes, insects and weeds, whereas others, which are more specific in their action, control only nematodes or fungi. Soil fumigation is not always an adequate substitute for soil steaming. Fumigants do not destroy all soil-borne viruses harbored in root debris and other plant parts.

For fumigation of soil in bulk piles or stacked flats, use cans of methyl bromide + chloropicrin (MC-2 or MB-C_2) at 0.3 kg/m.

The fumigants listed below are effective as preplanting treatments for greenhouse soil beds. Unless otherwise stated **amounts are for 100 square metres**. Do **not** apply fumigants when the soil temperature is less than 13°C. Ensure that all traces of the fumigant have escaped from the soil before seeding or setting transplants. To check this, set a few plants in the soil a few days before planting would normally begin, and watch their reaction. Always follow manufacturer's directions carefully.

1. Basamid: It is available in granular form (10% active ingredient). Distribute 2 to 4 kg/100 m^2 evenly on the soil surface. This may be done by hand when wearing rubber gloves or by means of a fertilizer spreader. Incorporate to a depth of 15 to 20 cm and seal the soil by watering, packing or covering it with plastic sheets. The soil must be aerated before planting. The amount of time for fumigation and aeration depends on soil temperatures. Fumes from Basamid when released from the soil will be harmful to plants in a greenhouse atmosphere.

2. Vorlex: It is available in liquid form and must be injected into the soil at a depth of 30 to 40 cm. Most growers have an injection system of their own mounted behind a rototiller. Use a rate of 6 L/100 m^2. After injection, seal the soil surface as for Basamid treatment.

Other fumigants

Methyl Bromide + Chloropicrin

- in pressurized cans containing 98% methyl bromide + 2% chloropicrin 7.5-10 kg
- as an injectable containing 67% methyl bromide + 31.8% chloropicrin 2.5-3.65 kg per 100 square metres (250-365 kg per ha)

Caution: Methyl bromide is a liquid which forms a poisonous gas when released from its container. The chemical is so poisonous to man and livestock that it must be applied with extreme caution and only by applicators who are specially licensed to use this type of fumigant. It must be used under a gas-proof cover, usually plastic. The licensed applicator must make the property owner and all assistants aware of all the precautions that must be taken when using this material. Before using, read the label carefully, wear the correct protective equipment (page 59) and read the section in the Pesticides Act, Alberta Regulations, which deals with methyl bromide soil fumigation. Also see licensing requirements for methyl bromide.

Nematodes

Nematodes are microscopic worms that feed on roots. Nematode activity can increase the severity of soil-borne diseases such as those caused by *Fusarium sp.* Pathogenic nematodes cause knots to develop on the roots of cucumbers and tomatoes, reducing plant vigor and ultimately causing wilting and death of the plant. A number of species are not harmful and may cause no apparent injury to the plant roots.

Nematodes may be spread by movement of contaminated soil into or within the greenhouse or by using contaminated tools. In many cases, nematodes are present in the soil when the greenhouse is established.

Hence, control measures should be taken before the first crop is planted.

Proper soil pasteurization with steam or chemicals can help in controlling nematode infestations. As root knot nematodes are known to move downward in the soil, pasteurize immediately after removing the crop. Steaming from the top is generally effective in killing nematodes in the top 15 to 24 cm of the soil. This will delay the onset but will not eliminate nematode attack. Another practical way of growing crops in nematode infested soils is to use straw bales. Nematodes cannot move in a medium like straw bales. If nematode-infested greenhouse soil is used, then steam it after placing it on the straw bales. Growing in plastic bags using ready-made mixtures or sawdust is another method of avoiding the nematode problem.

Damping-Off

This disease causes the seed to rot in the soil or the death of seedlings before or after emergence. The stem at soil level becomes water soaked and turns black or brown. Shrivelling of the tissue may follow.

Control measures include:

- using sterile media for growing seedlings.
- growing a bigger seedling in a 12-15 cm pot.
- treating seed with fungicides such as captan-vitavax mix or thiram.
- using warm water on recently transplanted seedling. Water early in the day. Allow soil surface to be on dry side overnight.
- providing good air movement.

Water Quality

Large quantities of water are used in a greenhouse for irrigation and fertilization. Have your water analyzed through your nearest district extension office. Ask for an analysis for irrigation purposes, along with an additional analysis for boron. Send a copy of the analysis to the greenhouse specialists at the following centres for interpretation of the results.

Alberta Special Crops and Horticultural Research Center,
Bag 200,
Brooks, Alberta
T0J 0J0
or the

Alberta Tree Nursery and Horticulture Centre,
R.R. #6,
Edmonton, Alberta
T5B 4K3,

Electrical Conductivity

- (EC) of water: for waters having a Sodium Absorption Ratio (SAR) of less than 6.0:
- water with an EC of 0.8 mmhos/cm or less is considered suitable for irrigation of cucumber, tomatoes and lettuce, under normal use conditions.
- water with an EC between 0.81 and 2.2 mmhos/cm is considered usable for irrigation, but only when accompanied by special management practices.

- water with an EC above 2.2 is not recommended as the sole source of water for irrigation. Consider collecting rain water from the roof of your greenhouse to mix with such water.

Special Management Practices

- Provide adequate drainage.
- Never allow the growing medium to become more than moderately dry. Maintain a higher moisture level in the rooting zone of plants than would be necessary with higher quality water. Reduce stress by designing a well drained mix.
- Analyze soil samples periodically to monitor the salt level.
- Leach periodically to remove excess salts from the medium. Use the following table as a guideline.

A more detailed analysis of all macro- and micro-elements is required when crops are grown in a substrate (rockwool, oasis, peat) with a limited rooting medium or Nutrient Film Systems. Appropriate adjustments can be made based on the analysis for the make-up of the nutrient solution. Water analysis will also give an indication whether the water source is contaminated or whether the concentration of specific ions such as fluoride (F) or boron (B) may be too high. In addition, the bicarbonate level has to be known so that the required amount of acid can be calculated to obtain a given pH. A list of the most common elements with the maximum concentrations is given in Table 6.

Water with an EC of 2.3 mmhos/cm or higher is normally not suitable for irrigation except when it can be mixed with good quality water, e.g., rain water.

General comments regarding the various elements are outlined below:

N, P, K, – Although, for fertilization purposes, these elements are usually added; their presence in high levels in raw water is indicative of contamination.

Ca^{++} and Mg^{++} – The levels provide adequatelevels of nutrition for most crops. Higher values do not necessarily mean toxicity, but can contribute to the hardness of the water.

HCO_3 – Bicarbonates are not very toxic but levels of 250+ ppm may create problems for plant growth. High levels provide a high alkalinity (pH), which over time may increase pH levels in the growing medium. The precipitation of calcium and/or magnesium carbonates causing leaf residue and the plugging of emitters is another disadvantage of high carbonate levels. High bicarbonate levels can be neutralized by using nitric, phosphoric or sulphuric acid (see Acidification).

Fe^{+++} – Iron in its oxidized form Fe^{+++}, has a low solubility and can therefore easily precipitate as amorphous iron hydroxide which results in the plugging of emitters. For drip irrigation systems, levels higher than 0.25 ppm are undesirable.

B – Boron can be quite toxic to plants and should be carefully controlled in substrate culture (less than 0.5 ppm) or for a recirculating system (less than 0.25 ppm).

Zn^{++} – Zinc can be found in water sources that have been in contact with galvanized metal (rain water from roof of greenhouse). Again the ions may accumulate in recirculating systems.

Table 5. Leaching guidelines as related to water quality

EC of water mmhos/cm	Parts per million salts (ppm)	Leaching requirements %	Recommended leaching interval	Interpretation water quality
0.35	245	5.0	12 weeks	excellent
0.40	280	6.0	9 weeks	very good
0.60	420	7.5	6 weeks	good
1.00	700	12.5	4 weeks	fair
1.40	980	17.5	3 weeks	permissible
1.80	1280	22.5	2 weeks	permissible
2.20	1540	27.5	1 week	excessive —too salty

Mn^{++} – Although manganese is not often a problem except under special circumstances (steam pasteurization), it is believed to be toxic at high levels.

Cu^{++}– Copper levels may be higher than 0.2 ppm if organic media are used.

Al, Mo, F – Aluminum (Al), molybdenum (Mo) and fluoride (F) are not commonly found at high concentrations in the water source. Fluoride, however, can cause serious damages to monocotyledons (lilies, dracaena, spider plant).

pH – Although hydrogen ions are not considered a nutrient element, it is important to include this factor because the availability of most nutrients are pH dependent. For instance most cations such as Fe, Mn, Ca as well as phosphates are more soluble at low pH, while molybdenum is more available at a higher pH. Most water sources in Alberta have a pH of 7.5 and above, due to high levels of bicarbonates. Acidification may be required (see acidification). A pH lower than 5.0 is harmful to rockwool media.

It should be remembered that above recommendations are valid for the use of substrate culture where there is a limited amount of leaching possible. Stricter guidelines are required for recirculating systems.

Table 6. Maximum desirable concentrations for specific ions for irrigation purposes in a greenhouse using substrates (rockwool, oasis or peat), or NFT systems.

Element	Substrates*	NFT*
Nitrogen (NO_3-N)	5.0	5.0
Phosphorus ($H_2PO_4^-$-P)	5.0	5.0
Potassium (K^+)	5.0	5.0
Calcium (Ca^{++})	120.0	60.0
Magnesium (Mg^{++})	40.0	25.0
Chloride ($C1^-$)	50.0	30.0
Sulphate ($SO_4^=$)	200.0	100.0
Bicarbonate ($HCO3^-$)	30-60	30-60
Sodium (Na^+)	100.0	50.0
Iron (Fe^{+++})	3.0	2.0
Boron (B)	0.5	0.25
Zinc (Zn^{++})	0.5	0.3
Manganese (Mn^{++})	1.0	0.5
Copper (Cu^{++})	0.2	0.1
Aluminum ($A1^{+++}$)	5.0	5.0
Molybdenum (Mo)	0.02	0.01
Fluoride (F^-)	1.0	1.0
pH (H^+)	5.0-7.0	5.0-7.0

*Maximum desirable (ppm)

Acidifying Water Supplies

Most of the water in Alberta cities is alkaline and moderately hard – it contains moderate amounts of calcium and magnesium. However, most rural water supplies are soft in nature. That is, they contain moderate or large quantities of sodium. Soft water or chemically softened water is not suitable for growing plants.

Hard water can be used for growing plants, but calcium can result in several problems, all of which can be alleviated by acidifying your water supply. Remember water pH will also affect the activity of chemical sprays. Many chemical sprays remain active longer in low pH solutions than in high pH solutions.

The calcium in Alberta water supplies is largely in the form of calcium carbonate or bicarbonate, which precipitates out as the familiar white deposit of calcium carbonate. The continued use of hard water for irrigation can lead to an accumulation of calcium in growing media, unless it is leached out by heavy nitrogenous feeding. When hard water is used for misting purposes, it can leave white scales on leaf surfaces, reducing photosynthesis.

Carbonates and bicarbonates interfere with the absorption of fertilizer as the amounts of these materials in the water become greater. Generally there are few carbonates in water until the pH of the untreated water is above 8.3, but carbon dioxide in the air dissolves in water and makes bicarbonates with various minerals in solution. Acidification of the water with phosphoric or sulphuric or nitric acid is a means of overcoming the injurious effects of carbonates or bicarbonates by neutralization. Do not add acid to the fertilizer concentrate tank.

Phosphoric Acid

This acid can be added through a fertilizer injector. An injector with two heads is suitable. Use injector heads meant for acids. An analysis of the water in terms of carbonate hardness is needed and can be obtained by subtracting non-carbonate hardness from total hardness.

Neutralizing 60 ppm bicarbonate requires 7 ml/100 L of 85 percent phosphoric acid.

Nitric Acid

Concentrated nitric acid (70% w/w) can also be used. It also provides some nitrogen feed helping to offset the cost of applying the acid. For each 1000 ml of concentrated nitric acid added to 1000 L of water, you are supplying 220 ppm of nitrogen.

To accurately assess the amount of nitric acid required for your particular water supply, send a water sample to the greenhouse specialists. An easy way is to send it through your district extension office.

A typical graph shown below is from a water sample containing 100 ppm of calcium. Here 275 ml of concentrated nitric acid are required to bring the pH to 5.9. This will also provide 60 ppm of nitrogen.

Note: This graph is an example only. Your water sample should be assessed individually.

Remember, concentrated acids are dangerous chemicals and must be handled with care. Always add acid to water not water to acid. Acidified water is corrosive and may eat away the metallic components of your irrigation system.

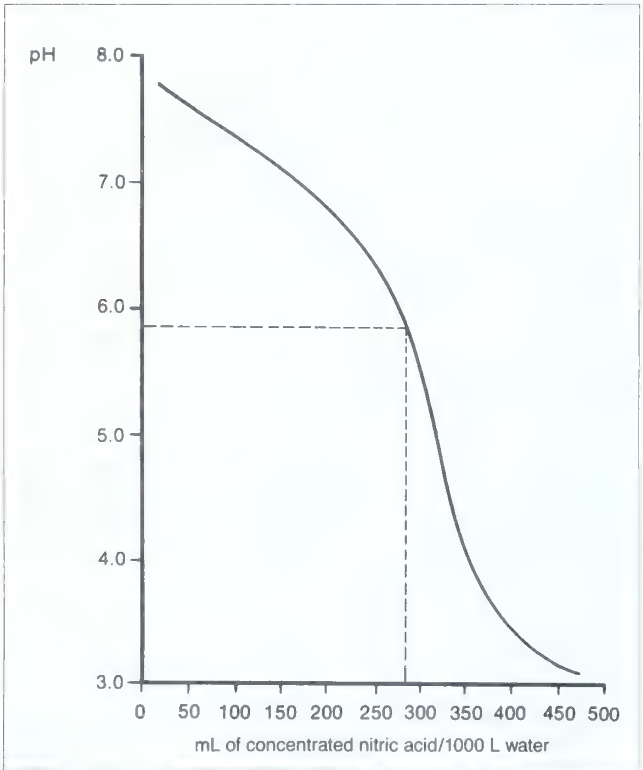

Figure 4: The effect of adding acid on the pH of a water sample.

Sulphuric Acid

Sulphuric acid can also be used to lower the pH of water. The amount has to be calculated based upon your water quality. If sulphates are more than 100 ppm then the use of sulphuric acid should be avoided.

Hydrochloric Acid

The use of hydrochloric acid should be avoided because of its chlorine content.

Chlorination

Chlorination of city water to reduce the population of various micro-organisms is accomplished by dissolving chlorine gas under pressure in the water. The amount that will go into solution is relatively small, and even though there may be a decided chlorine taste or smell, the water is safe for plants.

Fluoridation

Fluoridation of water is common in many cities in order to minimize tooth decay in children. When water is fluoridated, sodium fluoride is added to provide about three parts per million of fluoride in the water. The fluoride content does not hurt cucumber plants.

Boron

Boron is a fertilizer element that occasionally occurs in such quantities in Alberta water supplies as to be phytotoxic. When the level of boron is one or more parts per million, the water is considered unsatisfactory for use. There is no inexpensive method of removing boron and an alternative source of water must be considered.

Sodium

Sodium is another element that is usually present in well water throughout much of Alberta. It is not required for plant growth and can reach levels that are toxic to plants. If sodium is above 100 ppm, reverse osmosis should be considered to remove it, or an alternative source of water found. Water with up to 100 ppm can be used if the potassium level is maintained above that and special management practices are followed, e.g., regular leaching, good drainage, etc.

Pollutants

Pollutants of various kinds, some of which are toxic to plants, may be found in certain water supplies. Such materials may have been discharged inadvertently into a stream or buried where it later infiltrated into the ground water. Long lasting herbicides like Picloram (Tordon) can pollute water supplies and cause serious damage to crops. The best means of detection is to conduct a biological test with water intended for irrigation. Grow seeds of tomato and fababeans. Watch for any abnormal growth symptoms such as crinkling of new leaves or abnormal spindly leaves. This can serve as a test of the suitability of your growth medium as well.

Alkalinization

If water is acidic or pH needs to be raised, use Potassium bicarbonate. Use 50 g/100L to raise pH from 4.5 to 6.1 in 4 weeks time in peat bags.

Water Treatment

There are many different treatment processes for water. Treatment is specific to quality required for a particular purpose. A brief description of the different processes will be given as well as the feasibility for irrigation purposes.

Distillation – This process involves vaporization and subsequent condensation of the water. The principle is based on the fact that ions remain behind during the vaporization process. The final result is an EC of less than 0.1 mS/cm and a pH near neutrality. The process is very expensive.

Water Softeners – Water softeners are used to reduce the total hardness of the water, by exchanging the divalent cations (Ca^{++} + Mg^{++}) for sodium (Na^{+}) on an equivalent basis. Due to the electroneutrality of the exchange process, the concentration of soluble salts must be equal to or higher than the original source and moreover very high in sodium. Water softeners are not usually recommended for water used for irrigation and are used only as a boiler water treatment.

Deionization – Deionizers work on the same principle as water softeners except the water is passed through two exchangers. The first exchanges the cations in solution for hydrogen($H+$) ions and the second exchanges the anions for hydroxide (OH^{-}) ions. The resulting solution will have a lower EC than the original water source. The process requires more elaborate equipment and the regeneration chemicals are expensive. It is not often used in this industry, but may be useful for cut flower water preservatives.

Reverse osmosis – This process uses the principle that dissolved ions have a larger diameter than water molecules. The raw or untreated water source is forced under high pressure through very fine membranes that allow the water to pass through but not the ions. This process is expensive but for irrigation systems such as NFT, it may be the best option available.

Chemical treatments – An often raised question is whether or not the water can be treated chemically to eliminate high salts or reduce the concentration of specific ions. The answer to this question is generally no. There are some chemical treatments, however, which may provide a solution for certain specific problems. A few common examples are:

– the use of flocculants or coagulants. If a water source contains a large quantity of suspended particles (clay, silt, organic materials), the use of flocculants may be considered. One commonly used material is aluminum sulphate in combination with one of several organic compounds. Caution must be exercised due to possible phytotoxicity of the additives and the resulting low pH of the solution.

– the prevention of scale on the emitters of irrigation equipment. A treatment is often utilized to prevent the precipitation of calcium, magnesium and iron compounds. This is often a problem with low volume emitters or where overhead irrigation is used. The compound(s) that are employed are usually derivatives of sodium metaphosphate. The material possesses dispersing and deflocculating properties and inhibits crystallization of calcium carbonate, magnesium carbonate and iron hydroxides. The material does not appear to be phytotoxic and effectiveness depends largely on the actual conditions.

Disease Control

The alert greenhouse grower who can recognize plant diseases and knows how to deal with them will grow a more profitable crop. Some diseases can be prevented if they are recognized early, or their effect can be reduced if appropriate control recommendations are followed. To understand the

reasons for control recommendations, it helps to know about the diseases and the agents that cause them.

Definition of Plant Disease

Disease means a disturbance in function accompanied by the appearance of symptoms. The reaction of a plant to the cause of the disturbance produces the various symptoms by which we recognize disease. Whether the disease is important or not depends on how seriously it affects the yield and quality of the product.

Causes of Plant Diseases

Diseases are caused either by unfavorable conditions in the environment (non-infectious disease) or by micro-organisms (infectious disease).

Some common causes of non-infectious diseases in greenhouse crops are:

- Low temperature (e.g., chilling injury).
- Chemical injury (e.g., improper application of pesticide).
- Lack of nutrients (e.g., nitrogen deficiency).
- Excess water (e.g., "wet feet" condition from lack of oxygen around the roots).

Four types of micro-organisms commonly cause infectious diseases on greenhouse crops.

Bacteria – The simplest living organisms known to man are bacteria. Some are so small that 5,000 of them laid end to end would not measure more than one centimetre.

Many bacteria are beneficial to man. They feed on dead organic matter such as leaves on the ground and make more nutrients available to plants. Other species of bacteria are pathogenic and can enter plants through natural openings or wounds. Bacteria can be brought to plants by insects, flowing or splashing water and workers' hands. Some bacteria are carried in or on the seed.

Fungi – Fungi or molds are very common organisms. Fungi cannot make their own food and must feed on plants and organic matter. Although there are thousands of different kinds of fungi, the few that attack living plants concern us most.

For the most part, fungi reproduce by spores, which are very tiny bodies that look and behave much like seeds. Some fungi are capable of producing millions of spores, which can be spread by air currents, water, insects and other means. Under favorable conditions, a spore landing on a susceptible plant can produce a new infection centre. Often, the plant surface must be injured before the fungus can enter. Injury of plant parts is very common, and can be caused by insect bites, bruises, foliage rubbing together, pruning, etc. Under unfavorable conditions, some fungi produce special spores or other resistant structures that will allow the fungi to survive until more favorable conditions for infection exist. Certain fungi grow best at relatively high temperatures and low humidities (e.g., powdery mildew) while other prefer a cool, moist atmosphere (e.g., Botrytis grey mold).

Viruses – These tiny particles are so small that they cannot be seen through an ordinary light microscope. However they are responsible for some of the most serious diseases in plants.

Viruses produce a wide range of symptoms on plants. They are grouped into two general types: mottling, spotting or striping of the leaves; and yellowing, leaf curling or dwarfing of the plant. Often it is difficult to tell if a plant has a virus disease because no distinct symptoms are produced. Plant tissues cannot be penetrated directly by viruses and there must be a wound on the plant through which infection can take place. Aphids, leafhoppers and other insects with sucking mouthparts are the most important virus carriers. Tobacco mosaic virus (TMV) can be introduced into a greenhouse on contaminated cigarette tobacco and tomato and related plants can become infected. Viruses may also be carried in seed, tubers or bulbs.

Nematodes – Nematodes are small thread-like worms, usually from 0.5 to 1 mm long. Not all nematodes are harmful. Some feed on decaying organic matter and help build fertile soil. Plant parasitic nematodes may be found in the stems, petioles, leaves or roots. Those that feed on the roots cause the greatest amount of damage. Most plant parasitic nematodes possess a miniature hollow spear called a stylet. This stylet is used to puncture the cells of the root after which the nematode sucks out the contents of the cells. Some nematodes actually enter the root and spend most of their lives there. Others remain outside the root. Even though only a few nematodes may be feeding on a single root and causing only slight damage the wounds allow fungi or bacteria to enter and kill or seriously damage the plant. Some nematodes form knots or galls on the roots of the

plants. These structures slow the intake of water and minerals from the soil and cause the plant to be stunted.

Diagnosing Plant Diseases

The first step in combating a plant disease is to recognize that a problem exists. Next, one must identify the causal agent and determine whether it is non-infectious or infectious. This procedure is the art and science of diagnosis. The following are some important points to remember in diagnosing diseases of greenhouse crops:

- An accurate diagnosis is essential before timely and appropriate control measures can be applied.
- Examine all of the facts at hand. Like a detective, look for clues in cultural practices, unusual growing conditions, etc. Don't always assume that an infectious agent is the cause of the disease.
- Know the crop. Many disease problems, especially non-infectious ones, can be prevented if one has a sound knowledge of the growth characteristics, nutritional requirements and optimal environmental conditions for good growth.
- Learn to recognize the signs of insect and mite infestations. They can be easily confused with symptoms of certain diseases.
- Close observation of symptoms with the naked eye should indicate the general type of disease, e.g., leaf spot, wilt, root rot, etc. Closer examination of the surfaces of spots, cankers, etc., with a magnifying glass will often reveal the presence of spore-bearing bodies of fungi, bacterial exudates, insects or mites, etc. Diseased areas showing no evidence of surface growths could be young infections which may later develop structures or they may be the result of conditions causing noninfectious diseases.

Don't be afraid to consult a specialist for help. Alberta has regional plant diagnostic laboratories at Brooks, Olds, Vegreville and Fairview. Each laboratory is staffed with plant pathologists and entomologists. The addresses are given on page 66

Diagnosing Nutrient Disorders

What is a Nutritional Disorder

A nutritional disorder is a malfunction in the physiological processes of a plant caused by either an excess or a lack of a mineral element or elements and results in abnormal growth. External and internal symptoms can be expressed. Distinct symptoms are caused by a deficiency or excess of each essential element which can be used to identify the disorder.

The grouping of essential elements for plant growth is based on their mobility in the plant. Although there is a general gradation of mobility of elements, they are generally classified as either mobile or immobile.

Mobile elements are those which can be retranslocated. They will move from their original site of deposition in older leaves to actively growing regions of the plant such as younger leaves. As a result, the first symptoms will appear on the older leaves on the lower portion of the plant. Examples of mobile elements are:

Nitrogen	Potassium
Phosphorus	Magnesium
Zinc	

Immobile elements are those which are not retranslocated to growing region of the plant when the need arises. They remain in the older leaves where they were originally deposited. Deficiency symptoms, therefore, first appear on the upper young leaves of the plant. Immobile elements include:

Calcium	Iron
Boron	Sulphur
Copper	Manganese

Antagonism

Excess of one element affects the uptake of another element. This phenomenon is called antagonism. Some common nutrient element antagonisms are as follows:

Element in excess	Deficiency caused
Nitrogen	Potassium
Phosphorus	Potassium, Iron
Potassium	Nitrogen, Calcium, Magnesium
Sodium	Potassium, Calcium Magnesium
Zinc	Iron
Calcium	Potassium, Iron, Boron, Magnesium

Magnesium	Potassium, Calcium, Manganese
Iron	Manganese
Manganese	Iron, Zinc
Copper	Iron

Other Tips for Diagnosis

- Grow an indicator plant along with the regular crop. The susceptibility of different plant species to various nutritional disorders varies greatly. For example, if a crop of tomatoes is being grown, plant a few cucumbers. Cucumbers are very sensitive to boron and calcium deficiency. If such a deficiency occurs, the cucumbers will express symptoms from several days to a week before it appears in tomatoes. Tomatoes will show a magnesium deficiency earlier than cucumbers.

Weaker plants of the same species will show symptoms before the more vigorous ones.

- Every possible tactic must be employed to avoid a nutritional disorder in the main crop since, once symptoms are expressed in the crop, some reduction in yield is inevitable.

Common Terminology Used in the Description of Symptoms on Plants

Localized – Symptoms limited to one area of plant or leaf

Generalized – Symptoms not limited to one area but spread generally over entire plant or leaf.

Drying (Firing) – Necrosis - scorched, dry, papery appearance.

Marginal – Chlorosis or necrosis - on margins of leaves initially; usually spread inward as symptom progresses.

Interveinal chlorosis – Chlorosis (yellowing) between veins of leaves only.

Mottling – Irregular spotted surface - blotchy pattern of indistinct light and dark areas; often associated with virus diseases.

Spots – Discolored area with distinct boundaries adjacent to normal tissue.

Color of leaf undersides – Often a particular coloration occurs mostly or entirely on the lower surface of the leaves, e.g., phosphorous deficiency - purple coloration of leaf undersides.

Cupping – Leaf margins or tips may cup or bend upward or downward, e.g., copper deficiency - margins of leaves curl into a tube; potassium deficiency - margins of leaves curl inward.

Checkered (reticulate): Pattern of small veins of leaves remaining green while interveinal tissue yellows - manganese deficiency.

Brittle tissue – Leaves, petioles and stems may lack flexibility and break off easily when touched - calcium or boron deficiency.

Soft tissue – Leaves very soft, easily damaged - nitrogen excess.

Dieback – Leaves or growing points that die rapidly and dry out - boron or calcium deficiencies.

Stunting – Plant shorter than normal.

Spindly – Growth or stem and leaf petioles very thin and succulent.

After the symptoms have been observed closely and described, it should be determined whether the disorder is caused by something other than a nutritional imbalance. The following list of other possible disorders should be checked: insect damage; parasitic diseases; pesticide damage; pollution damage; water stress; light and temperature injury. Pesticide damage may cause burning if greater than recommended dosages are used on the plants. Also, the use of herbicides such as 2,4-D near a greenhouse may cause deformation of plant leaves closely resembling the symptoms of tobacco mosaic virus (TMV). Pollution damage may cause burning or bleaching of leaf tissue or a stippled effect (pinpoint-sized chlorotic spots) on leaves. Water stress, either lack of or excess of, will cause wilting (loss of turgidity) of leaves. Excessive sunlight or temperature may burn and dry leaf tissue, particularly on the margins.

SEEDLESS CUCUMBER PRODUCTION

General Information

A large number of European seedless cucumber cultivars are available to the grower. Individual cultivars respond differently to a given set of environmental, crop management and growing conditions. Hence, a grower must determine for himself which cultivar performs best under his greenhouse conditions. New cultivars should be tried first on a small scale.

All European cucumber cultivars set fruit without pollination and the fruits are seedless. Pollination causes off-shaped fruit, thus bees must be prevented from entering the greenhouse. To help overcome this, all- female (gynoecious) cultivars have been developed which bear almost 100 per cent female flowers. Male flowers can develop under high temperatures or other stress conditions on some cultivars. They should be removed as soon as they are visible.

Cucumbers are extremely sensitive to environmental factors such as low light, pollutants, cool air temperatures, low humidity, low carbon dioxide and high soluble salts. The success of a cucumber crop is dependent upon close adherence to the environmental needs and fertilizer requirements of the crop.

Recommended Cultivars

Farbio – The fruit has a very good green color and is slightly ribbed. Main stem fruit may be short if too many fruits are allowed to develop at the same time. The cultivar should not be pruned drastically. Fruit has a good shelf life.

Corona – The fruit is dark green and ribbed. Excellent shelf life makes it suitable for growth under a slightly lower temperature regime. Plant shows strong growth. There is strong resistance to gummy stem blight and botrytis. Suitable for long season cropping.

Farona – This cultivar has growth characteristics between Farbio and Corona. Strong vigorously growing plant. The fruit is dark green and ribbed.

Sandra – Fruit is deep green, slightly ribbed, averaging 38 cm in length. Intermediate neck. Resistant to gummosis and leaf spot diseases.

Toska – This cultivar displays good early vigor. Fruit has a good green color. The cultivar can be grown at slightly cooler temperatures.

Cargo – This is a new introduction from De Ruiter Seed Co. Trials at Alberta Tree Nursery & Horticulture Centre, in Edmonton, in NFT and peat bags produced excellent yields. Very good dark fruit color. Plant habit is open, side shoots short and sturdy.

Mustang – A new introduction from Bruinsma Seeds. Grower trials have been encouraging.

New varieties are constantly being introduced. Contact the greenhouse specialists for more up-to-date information.

Seedling Production and Timing

Either one or two crops of greenhouse cucumbers are commonly produced per year in Alberta. Use the following table as a guideline for spring crops:

The crop can be continued until September, provided diseases and insects are kept under control and plant vigor maintained. For establishing a fall crop, the plants are pulled by the end of July, and a new crop planted by the first week of August. The fall crop may be maintained until December in southern Alberta; till the end of October in central Alberta and the end of September in northern Alberta. This arrangement can vary depending on marketing, fuel costs and disease susceptibility.

Location	Seeding date	Transplanting date	Approximate harvest dates
southern Alberta	Dec. 1 to Dec. 25	Dec. 25 to Jan. 20	Feb. 15 to Feb. 29
central Alberta	Jan. 1 to Jan. 14	Jan. 20 to Feb. 7	Feb. 20 to Mar. 7
northern Alberta	Jan. 30 to Feb. 7	Feb. 28 to Mar. 7	Apr. 15 to Apr. 20

Carbon dioxide enrichment should be applied throughout the propagation period, and is useful to the plants as soon as the seed leaves are fully expanded. Carbon dioxide enrichment should be at a level of 1000 parts per million. The young plants are tender and easily damaged by excessive levels of carbon dioxide. Well-sealed greenhouses may need a short period of venting or fresh air intake once or twice a day during spring, especially under damp calm conditions. It will reduce the risk of the build-up of toxic by-products of combustion.

Artificial Illumination

Cucumber seedlings are very light-dependent and the vigor and color of their early growth is proportional to the light levels received. Sowings in December and January should always be under the best circumstances. Glass should be cleaned before sowing to allow maximum light transmission. Artificial lights are not used in Alberta, however, they are commonly used in Europe. Lighting is expensive, and it is not always easy to determine the benefits that result from its use. Lighting techniques vary, as do types of lamp and installation. As a general rule, 12 to 16 hours lighting in each 24 hours is standard, using illumination levels between 7,500-15,000 lux. Continuous lighting should be avoided because cucumbers may produce an unsatisfactory growth pattern and develop scorches caused by excessive radiation of certain wavelengths. High pressure sodium lamps of 400 or 1000 watts are commonly used. A 400-watt lamp is enough to cover 10 m^2 of growing area.

Raising Healthy Seedlings

Seed Sowing

–select plump seed only

–sow seeds in plastic trays filled with sand, sand-peat or a commercial mix

–maintain the strictest hygiene because cucumber seedlings are very sensitive to root diseases, especially pythium

–space seeds at 2.5 cm square pushed into the compost to 1 cm depth

–water with a fine hose - despite traditional opinion, there seems to be little significance in the orientation of the seed when it is sown, and a seed placed flat will germinate and emerge at the same rate as one placed on edge or on its end

–maintain a temperature of 27°C. Slow germination produces a poor quality plant, and the aim should be to produce a seedling with fully expanded cotyledons within 48 hours of sowing

–prick-off into moist propagation pots as soon as the cotyledons are fully expanded. Plastic pots, peat pots, walehide pots are commonly used. Pot diameter can range from 12 to 15 cm according to the stage at which it is intended to move plants into their planting positions

–propagation compost can be your own or a commercial mix

–after emergence, drop air temperature to 24°C until plants are established. After that night temperature can be lowered to 21°C. Minimum day temperature is 23 to 25°C, venting at 27°C.

As an alternative to tray sowing, it is possible to sow directly into peat blocks. Growers use home-made blocking compost or commercial mixes. The two biggest problems with sowing in peat blocks are watering and temperature. Blocks should be watered as frequently as necessary to prevent drying out at any stage and they should be handled carefully at all times to prevent damage. It is preferable to use chitted seed for sowing in blocks. For hydroponic culture, use 15 cm rockwool blocks which can be directly seeded or into which seedlings can be transplanted. The blocks should not be allowed to dry out at any stage. A complete fertilizer 1:1 N:K fertilizer with all trace elements should be started when true leaves are emerging.

Early Culture

The peat-based composts should always be kept moist and never allowed to dry because they are difficult to rewet and root damage can often result. Liquid feeding should start when the fourth or fifth leaf has emerged from the head and can be applied continuously onward. If the compost dries at any time a clear watering should be given to wet up the substrate before reverting to liquid feed. This will reduce the risk of root scorch.

Apply 10-52-10 or 9-45-15 at a rate of 100 g/L of stock solution at 1:100 injector ration. Apply once a week for three weeks. In addition mix equal parts of potassium nitrate and calcium nitrate and use 100 g/L of stock at 1:100 ratio. This fertilizer can be applied as a constant feed.

Space the plants as they grow. Don't allow them to tip over. Stake them properly if the need arises.

Growing Systems

Root diseases and nematodes have necessitated the development of isolated growing systems. Many growers in Alberta use peat bags, nursery containers with 1:1:1 soil:peat:vermiculite mix and various hydroponic systems. Rockwool culture is also practised in Alberta.

Soil Culture

A number of different soil-based systems are used for cucumber production. They are: direct planting into soil; planting on strawbales with a top cap of soil; or using 50 per cent soil with peat moss and vermiculite in containers. Any system that uses the soil requires annual sterilization either by steaming or by the application of chemicals. Please refer to the general soil section for management. The nutritional status of the soil should be determined before planting. Base fertilizer applications should be made according to the soil analysis.

Soil:Peat:Vermiculite

Cucumbers can be successfully grown in a homemade blend of 20 per cent soil, 50 per cent coarse peat moss and 30 per cent coarse vermiculite. Use 25 litre plastic bags or containers with drainage holes 2.5 cm above the base. The mix should be sterilized properly. It is advisable to put gravel or straw at the base of the pot to improve drainage.

Peat

Cucumbers are grown in commercially prepared peat modules. Two types of modules are available. One type is made from a woven type of plastic and the other is made from 2 mil plastic. These bags demand different water management because it is easy to leach nutrients from the woven type. Each bag usually contains about 50 litres of compost and is suitable for growing two cucumber plants. The composition of a mix is given on page 9. Research at the Alberta Special Crops and Horticulture Research Center, Brooks, has shown that peat modules can be used for two years.

Rockwool

Rockwool is an inert growing medium that is compressed into slabs, commonly 190 x 30 x 10 cm in size. It has a high water-logging capacity, but also aerates well. It has no nutrient retaining properties, hence continuous liquid feed is necessary. Rockwool as a growing medium for cucumbers produces satisfactory crops, although there is no indication that the production level is any higher than when using soil.

The layout generally consists of a base of styrofoam insulation with a groove on its upper surface into which a root-zone warming pipe can be fitted. Rockwool slabs lie on this, wrapped in a white or black plastic sheet. The plastic wrap is slit to allow excess solution to drain away just above ground level. Plants are raised in 10 to 15 cm plastic wrapped rockwool blocks, which are then simply placed at the appropriate plant density along the row. Bottomless plastic pots appeared satisfactory in the trials at Brooks. Peat pots may develop capillary problems, so they are not recommended.

A drip irrigation system is necessary with one nozzle for each propagating block and one nozzle on the rockwool slab. Some cucumber cultivars may respond better than others.

Nutrient Film Technique

NFT was developed by Dr. A. Cooper of the Glasshouse Crops Research Institute, Littlehampton, England. The nutrient solution is contained in a large catchment tank from which it is pumped through a manifold header line situated at the top of the rows of plastic channels. Seedless cucumbers can be grown in NFT. Early yields are usually high but it is difficult to maintain long-season vigor. Fifteen weeks after planting, the roots die and plants generally do not recover. Research at the Alberta Tree Nursery and Horticulture Centre, Edmonton, showed that using sodium or potassium silicate in the solution can extend harvest by another 4 to 5 weeks. Commercial experience with NFT system is very encouraging.

Sawdust

Sawdust provides an inexpensive, well drained and initially a disease-free environment for root development. Use a moderately fine sawdust because as the water distribution through the bags

is more uniform. Douglas fir (*Pseudotsuga menziesii*) and Western hemlock (*Tsuga heterophylla*) are the main types of sawdust commonly used, although other kinds of conifer sawdust have been used successfully. Aviod large proportions of Western red cedar (*Thuja plicata*) in the sawdust. Before using the sawdust, check its conductivity to determine if there has been a salt accumulation. An analysis for manganese is also recommended because this mineral can accumulate in the wood to levels toxic to cucumbers. Moisture does not spread well laterally in pure sawdust. Place a 1 to 2 cm thick layer of clean, sterilized sand over the top of the sawdust to improve moisture distribution.

White plastic bags (15 x 25 x 30 cm) are recommended. They contain 10 L of sawdust for one cucumber plant. Bags should have some drain holes. Bags and sawdust are changed yearly with the crop. Other containers can be adapted or plants may be grown in beds. Beds are typically constructed with sides of wood and the bottom of shaped ground for drainage. The bottom is covered in plastic to prevent rooting out by the plants. The beds must contain 10 L of sawdust for each cucumber plant.

Containers can be filled by hand or by using a funnel arrangement on a stand. Electrically driven augers or belted elevators with a foot operated switch work well and give the operator good control of the sawdust flow.

Bags or containers are placed in the greenhouse on drop sheets of plastic. White is preferable because it reflects more light. When establishing a greenhouse for sawdust culture, ensure good in-ground drainage to get rid of the excess water used for leaching.

Standing Out

Young plants should always be spaced out so that their leaves do not overlap. Plants should be properly supported with split canes to which they are attached by 5 cm plastic clips. Care must be taken that the plants do not become chilled while they are being moved between the propagation area and the growing house. They should not suffer physical damage. If the plants are not to be allowed to root into the growing medium immediately, they should be stood on plastic strips, discs or hardboard squares. Ensure that they do not stand in a pool of water after watering.

Planting

The stage of planting depends on the growing program. Early spring crops are planted when they have developed 4 or 5 true leaves and roots fill the propagating pot. It is important that there should be no delay beyond this stage because excessive root development within the pot can inhibit rooting out after planting. It will retard establishment into growing medium. Later crops can be safely planted at an earlier stage, because better growing conditions make it easier to establish a satisfactory balance between vegetative growth and fruit development.

To plant into soil, a planting hole should be made a little deeper than the depth of the propagating pot. Ensure the pot sits well down into the bottom of the hole. If the plants have been raised in disposable pots, water the plants and knock them gently out of the pots before planting. Discard any plants with brown roots or a poor root system. Do not handle the plants by the stem. Lightly firm the growing material around the root ball. Plants should be watered in by hose with about 500 ml of water per plant. Planting into peat should be carried out in a similar way, except that the root ball or pots should be planted only to half its depth if the peat has already been wetted.

Sawdust bags should be moistened with warmed water prior to planting out. Do not allow bags to dry out until a full root system has developed. This may require hand watering the bags three to four times a day in the first few weeks after planting.

Rockwool blocks should be placed on rockwool slabs and fertilizer applications should start immediately.

Planting Density

The distance between the rows should take into account the width of the greenhouse, the position of posts, the need for workers to move down the rows and the training system that will be used. If the V-system is used, the minimum average row width is 1.5 m and spacing in the row can vary from 40 to 50 cm. If the plants are trained vertically, row spacing can be reduced to one metre while the distance between the plants should be increased to 70 to 80 cm. In any case, the plant population should not exceed 1.6 plants per m^2.

Establishment

Early culture after planting should be aimed at encouraging rapid rooting into the growing medium and striking a balance between vegetative and fruit growth. Plants should be kept healthy and free from stress. For the first week or two, watering should be carried out carefully. Water should be applied to the root zone whenever drying back starts, but only enough water should be given to keep the root ball moist without excessive wetting of the growing mix.

Excessive amounts of water will result in too much vegetative growth and cucumbers will not fill in.

The principal aim should be to maintain a high humidity in the air, even if this means limiting ventilation under some conditions. Proper humidity levels are very critical when bags are used for growing. Damp the walkways more frequently. Use overhead sprinklers, stopping in time for the plants to dry off before dusk.

Young cucumber plants are very susceptible to a number of root rot fungi. *Pythium* infection is common during the establishment period. Avoid cold water shock to the plants. Follow the recommendations to control damping off.

Temperature

The temperature of the growing mix is extremely important for cucumber production. The minimum temperature is 20°C while from 22 to 24°C is generally considered to be the optimum.

Temperature can be used to maintain the balance between fruit production and vegetative growth. By lowering the night temperature, vegetative growth and strong flower development are promoted. Conversely, by raising the night temperature, rapid fruit development will result. The following program is suggested.

First four weeks after planting:
19-20°C nights,23-24°C days

Until two weeks after picking starts:
18-19°C nights,23-24°C days

Until the end of the crop:
17-18°C nights,23-24°C days

Although the program proposed above will give satisfactory crops, a number of minor modifications may be made by the experienced grower to suit particular circumstances. Lower than recommended temperatures, particularly when the reduction is sudden, can cause malformation of developing fruit, and if the low temperature persists there may also be pale surface scar tissue formed on the fruit.

Carbon Dioxide Enrichment

Carbon dioxide enrichment is of economic value for cucumbers, especially from January to May. The level of enrichment should, in general, be limited to 1000 ppm, particularly during propagation. Mature crops can tolerate between 1500 and 2000 ppm. Enough air should be available to burn natural gas to generate carbon dioxide. This can be achieved by opening the ridge vents 4 to 6 cm. Modern carbon dioxide generators have proper exhaust and fresh air intake systems. Carbon dioxide should also be used in summer before ventilation by exhaust fans starts.

Irrigation

An adequate supply of water of suitable quality is necessary for cucumbers. Water with high levels of sodium or chloride (more than 100 ppm), can cause problems, particularly on crops grown on soilless media. Hard water increases the risk of blockages in the irrigation system, especially if phosphates are included in the liquid feeding programs. Water quality is more critical for crops in rockwool or NFT. Please refer to water quality on page 11 for special management practices.

Cucumbers require a good deal of water. During peak consumption in the summer months, the crop will require from 30 to 40 L/m^2 per week. The amount of water used is very closely linked with the total amount of light radiation. In Europe, solarimeters or evaporimeters are commonly used to determine water use.

Many application methods are used, depending on the growing system. Crops grown in soil are watered by 2-3 cm diameter PVC or black plastic pipe with 360° nozzles. These nozzles are usually 0.5-0.8 m apart. The pipe runs in the middle of the growing bed. Watering frequency varies from two or three times weekly from December to March to two or three times daily from April to September. If plants are watered less frequently, make sure that the fertilizer solution is more concentrated.

Trickle or drip systems are necessary for crops in peat, sawdust bags or rockwool slabs. Uniform application is important; otherwise, some areas

will be dry while others will be waterlogged. With crops grown in peat or sawdust bags, there is a much smaller reserve of water available and applications may need to be made up to eight times a day. Once the peat or sawdust bags are properly wetted, they should be slit or have holes punched in them to allow drainage of excess water. Slits are made about 2.5 cm above the floor. The volume below the slits acts as a reservoir which reduces the risk of the peat drying back between waterings. The same thing can be done in the case of rockwool systems, which also have a low water capacity and need frequent applications of small volumes of water.

Feeding

Soil

Cucumbers must have a proper balance of nutrients continuously to produce a full crop of high quality fruit. Feeding programs should be developed which maintain low soluble salt levels but maintain soil nutrient levels in the range found in table 7.

Soils differ widely in the amounts of nutrient reserves that they can supply to plants. A highly fertile soil probably has enough of all the nutrients for the production of one good crop, but continued cropping will deplete these amounts. Light sandy soils have very limited reserves. The nutrient amounts present in a soil can be determined from a soil test.

It is therefore necessary to use a large amount of fertilizer for good crop production, especially in light sandy soils. Depending upon the amount of fertilizer or manure premixed, fertilizer application should start two to three weeks after transplanting. If manure has been used, enough potassium will be available to last until the first stem flush of cucumbers. Levels of nitrate nitrogen and ammonium nitrogen should be regularly measured, especially when the growing medium has been pasteurized by steaming, or chemicals like Vorlex or Basamid have been used.

High analysis soluble fertilizers can be metered into the irrigation water.

A schedule for the weekly application of fertilizers is shown in the following table. The schedule is based upon experience with growers in Alberta at the Alberta Special Crops and Horticulture Research Center, Brooks, and the Alberta Tree Nursery and Horticulture Centre, Edmonton. To estimate the fertilizer needs of the crop, growth should be carefully watched and the tissue and leaf test should be made regularly. No formula can take the place of good judgment. The schedule should be used only as a guide and should be adjusted to suit the fertility level and the progress of the crop in each greenhouse. Omit the feeding completely if cloudy weather prevails for a week. Reduce the feeding by one-half if cloudy weather prevails for three to four days.

When a crop is planted in July-August as a fall crop, start feeding from week 24 onward. If water contains 100 ppm or more of calcium, then reduce calcium nitrate (15.5-0-0) by one-half and increase 34-0-0 by 0.2 kg/100 m^2. For high fertility soil, apply fertilizer at half the recommended rate until around the thirteenth week, then resume application at the recommended rate.

Liquid Feeding of Soil Grown Crops

Several methods of liquid feed application are available commercially, any of which is suitable provided it gives a known and consistent rate of dilution. Two or three head fertilizer injectors with dilution ratios of 1:100 or 1:200 are commonly used. One head is used for calcium nitrate only and the second head is used for phosphate and sulfate containing fertilizers.

The rates listed below are based on grams of fertilizer/100 L of water. If a 1:100 injector is used, then dissolve the fertilizer amount in one litre of water. Double the rates if injector ratio is 1:200.

Immediately after planting apply monoammonium phosphate or a commercial plant starter 100 g/100 L. Apply about one litre per plant, two times a week depending on weather conditions. Continue starter feed for 3-4 weeks.

Main feed, 4 weeks after planting:

Stock Barrel A:		
	Potassium nitrate	100 g/100 L
	Monoammonium phosphate	50 g
	Magnesium sulphate	50 g
	Chelated trace elements*	3 g
Stock Barrel B:		
	Calcium nitrate	75 g
	Use as constant feed.	

*Commercially available formulations are generally satisfactory. Check with your greenhouse specialist if copper is more than 0.3% in the mix.

Table 7. Guide to weekly application of fertilizer for spring crop of seedless or seeded cucumbers grown on soil.

Week after transplanting	10-52-17 or 11-48-0 or 12-53-0	13-0-44 potassium nitrate	15.5-0-0 calcium nitrate	34-0-0 ammonium nitrate	21-0-0 ammonium sulphate	Epsom salts magnesium sulphate	Trace elements
	Recommended Fertilizer - kg/100 m^2						
1	1.0						
2	1.0						
3	1.0						
4		0.5	0.5			1.0	
5		0.5	0.5				
6		1.0	1.0				
7		1.0	1.0				
8		1.0	1.0	0.5		1.0	1.0
9		1.0	1.0	0.5			
10	1.0	1.0	1.0	0.5			
11		1.0	1.0	0.5			
12		1.0	1.0	0.5		1.0	
13		1.0	1.0	0.5			
14	1.0	1.0	1.0	0.5			
15		1.0		0.5	0.5		
16		1.0		0.5	0.5	1.0	
17		1.0	0.5	0 .5			
18		1.0		0.5	0.5	1.0	
19	1.0	1.0	0.5	0.5			
20		1.0		0.5	0.5		
21		1.0	0.5	0.5			
22		1.0		0.5	0.5	1.0	
23		1.5	0.5	0.5			
24	1.0	1.5		0.5	0.5		
25	1.0	1.5	0.5	0.5			
26		1.5		0.5	0.5		
27		1.5	1.0	0.5			
28	1.0	1.5		0.5	0.5		
29		1.5	1.0	0.5			
30		1.5		0.5	0.5		
31		1.5	1.0	0.5			
32		1.5		0.5			

Main feed, 8 weeks after planting:

Apply as above, but increase 13-0-44 to 150 g and calcium nitrate to 100 g. Provide an additional 3 g/100 L of iron chelate if iron deficiency appears. Commercially available formulations are 20-5-30 or 20-10-30. They can be used at a rate of 100-150 g/100 L, instead of potassium nitrate and monoammonium phosphate. Use calcium nitrate as suggested above. If new growth is poor, add ammonium nitrate at a rate of 50 g/100 L. If magnesium deficiency appears as interveinal chlorosis on lower leaves, increase magnesium sulphate to 100 g. Modify the feeding program according to the soil test results, leaf analysis and condition of the crop.

Peat Systems

The reserve of nutrients in peat or peat based media is less than in soil, and the levels can change rapidly. Therefore, regular and accurate liquid feeding is required. Peat should be analyzed regularly throughout the season and adjustments in the fertilizer program made accordingly.

Commercial peat bags contain different amounts of nutrients, depending upon the manufacturer. It is advisable to use proprietary

fertilizer formulations. The following fertilizer program used at the Alberta Special Crops and Horticulture Research Center, Brooks, gave satisfactory results.

Start immediately after planting into peat modules and continue up to 4 weeks.

Plant starter fertilizer

10-45-15	
or	
10-52-10	80 g/100 L
or	
10-52-17	
+	
potassium nitrate	100 g/100 L

The growing mix is dry in the beginning. Moisten the bags with the above mentioned fertilizer solution once before planting at a rate of 600-800 ml/plant. Immediately after transplanting into the peat modules apply another 600 to 800 ml of plant starter fertilizer solution. Thereafter apply 4 to 5 L/plant/week, approximately 2 to 3 times/week depending on weather conditions. The plants should be kept on the dry side. Do not soak the peat modules or there will be too much vegetative growth and a poor fruit set, especially in dull weather.

Main feed begins 4 weeks after planting

Potassium nitrate	100 g/100 L
Monoammonium phosphate	30 g
Magnesium sulphate	50 g
Chelated trace elements*	5 g
Iron Chelate	2 g
Calcium nitrate	50 g

* Commercially available formulations are satisfactory.

When fruit is setting well, increase liquid feed to 2-3 L per plant per day. Run the plants on the wet side.

Eight weeks after planting increase potassium nitrate to 150 g/100 L and calcium nitrate to 75 g.

Take leaf analyses at regular intervals and make adjustments accordingly.

Extra nitrogen can be made available from ammonium nitrate or urea between April 1 and October 30 when vegetative growth is desirable.

Rockwool and Nutrient Film Technique

In the case of rockwool systems or nutrient film growing there is no reserve at all of nutrients in the rooting area. The supply of nutrients has to be very accurate and constantly monitored. The following fertilizer program has been successfully used at the Alberta Special Crops and Horticulture Research Center, Brooks, and the Alberta Tree Nursery and Horticulture Centre, Edmonton.

Rockwool: up to 4 weeks from planting

Potassium nitrate	75 g/100 L
Monoammonium phosphate	50 g/100 L
Magnesium sulphate	50 g
Chelated trace elements	6 g
Calcium nitrate	50 g/100 L

after 4 weeks and up to 8 weeks

Potassium nitrate	100 g/100 L
Monoammonium phosphate	40 g
Magnesium sulphate	50 g
Chelated trace elements	6 g
Calcium nitrate	75 g/100 L

after 8 weeks

Potassium nitrate	150 g/100 L
Monoammonium phosphate	40 g
Magnesium sulphate	50 g
Chelated trace elements	6 g
Iron chelate	2 g
Calcium nitrate	100 g/100 L

– Ammonium and urea type nitrogen should not be used in NFT systems.

Potassium nitrate	100 g/100 L
Monopotassium phosphate	20 g
Potassium sulphate	50 g
Magnesium sulphate	50 g
Chelated trace elements	8 g
Iron Chelate	2 g
Phosphoric acid 75%	10 ml
Calcium nitrate	100 g/100 L

Use half strength for the first two weeks.

Sawdust

After planting out, place drippers on the bags at the edge of the rootball. Allow three drippers per plant if no sand is used on the bags. Do not place a dripper near the stem as it may encourage the development of crown rot. Full strength fertilizer solution can be given to the plants.

Time fertilizer applications at regular intervals during the day such as hourly or half-hourly if using a time clock system. Allow 10 to 20 per cent leaching to ensure there is no soluble salt accumulation. Start with 800-1000 ml per day and adjust feeding volumes upwards as sunlight and size of plants increase. Rates given to mature plants will be 4 to 7 L per day. Keep the sawdust moist but not saturated. Feeding once or twice

Table 8. Feeding program for cucumbers in sawdust

	Concentration (ppm)	for 1000 L grams	millimol/L
A. Calcium nitrate (15.5-0-0) (19% Ca)	116 N 142 Ca	750	NO_3 - 13.0
Magnesium sulphate	25 Mg	250	H_2PO_4 - 1.5
Monopotassium Phosphate (0-53-34)	46 P 56 K	200	K - 7.0
Potassium Nitrate (13-0-46)	65 N 190 K	500	Ca - 3.5
Potassium chloride (0-0-60)	40 K	80	Mg- 1.0
or			
Potassium sulphate (0-0-50)	40 K	96	SO_4- 1.0-1.5
B. (Where water pH exceeds 7.5)			
Calcium nitrate (15.5-0-0)(19% Ca)	116 N 142 Ca	750	
Magnesium sulphate	25 Mg	250	
75% Phosphoric Acid	46 P	200	
Potassium nitrate (13-0-46)	65 N 170 K	500	
Potassium chloride (0-0-60)	96 K	195	
or			
Potassium sulphate (0-0-50)	96 K	230	

Minor elements for sawdust	Concentration (ppm)	for 1000 L grams	micromol/L
Iron chelate (10% Fe)	1.0 Fe	10.0	Fe - 18.0
Manganese sulphate (28% Mn)	0.3 Mn	1.07	Mn - 5.5
Boron (20.5% B)	0.5 B	2.430	B - 46.0
Zinc sulphate (36% Zn)	0.1 Zn	0.276	Zn - 1.5
Copper sulphate (25% Cu)	0.03 Cu	0.120	Cu - 0.5
Molybdenum (54% Mo)	0.05 Mo	0.092	Mo - 0.5

during the night reduces plant stress and has been shown to be beneficial. Ensure that the feeding solution temperature is 20°C (minimum) when applied.

Formula A may require the addition of sulphuric or phosphoric acid to lower the pH of the fertilizer solution. A milky precipitate after tank mixing indicates the need for pH adjustment.

If the water is particularly alkaline, phosphoric acid may be used as the phosphorus source. Contact the greenhouse crops specialist for further information on pH adjustment.

Commercially available micro-element mixes can be used satisfactorily. Adjustments must be made in the above feeding program depending on water quality. For example, if the calcium levels are greater than 100 ppm in the water supply, calcium nitrate has to be reduced. Additional nitrogen must be made available through the use of ammonium nitrate. Contact the greenhouse crops specialist at the Alberta Tree Nursery and Horticulture Centre, Edmonton, for further recommendations.

Training the Plants

The plants can be trained to a V-cordon or to a vertical cordon system. The largest amount of available light is intercepted when the V-System is practised. Also, fewer rows are required because of the greater distance between rows and, if the crop is grown on straw bales or in heated soil, a saving on labor and materials is obtained.

The V-system can be described as follows: Two crop wires are placed 2.2 to 2.5 m above ground

over each row of plants, the wires spaced so that they are 60 to 80 cm apart. The strings for the plants are then tied alternately to the overhead wires so that the plants are inclined away from the row on each side. The plants will then be growing in a V-arrangement, down the row, allowing light to fall more uniformly on the plants and allowing fruit to hang away from the main stem.

Support cucumber plants by tying them to strings that are suspended from a horizontal wire. Use heavy sisal or polyethylene twine for the supporting string. Loosely attach the supporting string around the main stem at the base of the plant with a nonslip knot. Do this a week or so after transplanting when vertical growth is beginning. As the plants grow, loosely wind the main stems around the string, or attach the stems to it with special plastic clips. The plastic clips should be tied at the base of the leaf. Do this frequently enough to prevent any sagging or stem bending. If the mainstem gets broken, then encourage a side shoot to develop and train it as the main stem.

Pruning

You can use various pruning and trimming systems to avoid excessive growth and maintain fruit production. On gynoecious types, female flowers and lateral branches are produced in every leaf axil throughout the plant. The goal of pruning is to leave the maximum amount of leaf surface and developing fruit that the plant can support, but not so much that it interferes with air circulation or seriously reduces the supply of light to lower leaves. A basic practice in all pruning systems is to remove all lateral branches and main stem fruit from the first five to seven nodes. If not removed, the fruit on these lower nodes will touch the bed surface during development, becoming second-grade fruit because of curvature or unmarketable because of decay at the tip. Leaving fruit at the lower nodes will result in fruit aborting at the upper nodes.

Renewable Umbrella System

This is one of the more commonly practised training systems. It is simple and not labor intensive. Each plant must be considered individually, on the basis of its vegetative vigor and fruit load. A correct balance between these two factors must be maintained.

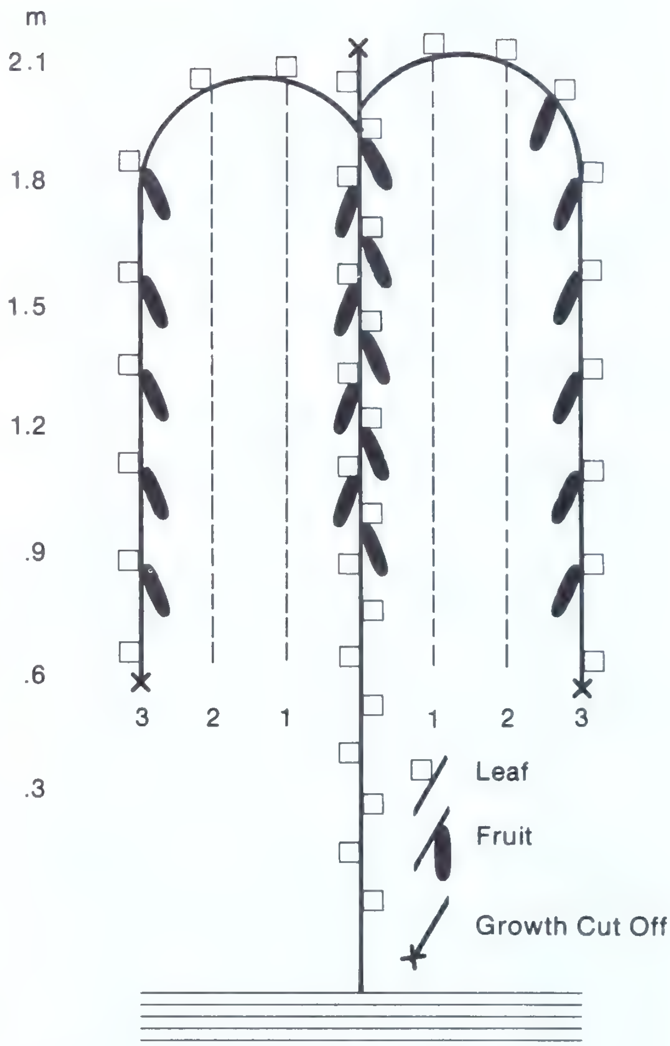

Figure 5. Pruning cucumbers

If too many fruits are allowed to form at any one time, a large proportion will abort because the plant may not have sufficient food reserves to develop them. If a heavy load of fruit sets, many fruits will be malformed, curved, short or poorly colored, and therefore unmarketable. Remove them at an early stage. Multiple fruits in one axil should be reduced to one.

Too much vegetative growth is detrimental, because leaves may develop at the expense of fruit. A dense canopy of leaves will shade fruits from sunlight, causing them to be pale in color.

a) The main stem should be stopped at one leaf above the wire. Pinch out the growing point at that level. Tie a small loop of string around the wire and below the top leaf, so that the plant will not slide down the main string.

b) Do not allow fruits to develop on the main stem up to about 130 cm.

c) Before they grow out, remove all laterals in the leaf axils on the main stem, except two at the top.

d) The top two laterals should be trained over the wire to hang down on either side of the main stem. Allow these to grow to two-thirds of the way down the main stem.

e) All secondary laterals should be removed except two at the top.

f) While the fruit on the first laterals is maturing, the second laterals should be allowed to grow out and downward.

g) When the fruits on the first laterals have been harvested, those laterals should be removed back to a strong shoot, allowing the second laterals to take over.

h) Repeating steps (5), (6) and (7) in this renewal system will maintain productivity of plants.

i) Remove old large leaves which have become unproductive. Snap the leaves off close to the main stem. Do not leave long stubs hanging on.

Good quality fruit will not develop unless there is a continuing production of lateral shoots. It may be necessary to resort to major pruning to stimulate growth. In this case, it is better and less costly to cut out whole unproductive laterals than to snip back the tops of several weak ones.

Fruit Harvest

Cucumbers are harvested when they are uniform in diameter and meet the minimum grade standard for Canada No. 1. They are cut from the plant two to three times a week, leaving a small stalk attached to the fruit.

Grading and Packing

After harvesting, the cucumbers are graded as either Canada No. 1 or No. 2 based on: size; shape; color; maturity; freedom from disease, injury, defects and damage; cleanliness and size. Canada No. 1 cucumbers must be a minimum of 30 cm in length, and if harvested from October 1 to March 31, 38 mm in diameter; and if harvested from April to September 30, 42 mm in diameter.

Cucumbers are shrink-wrapped to increase shelf life and are packaged in twelves in cardboard boxes. Cucumbers should be handled carefully because they bruise easily.

Storage

Cucumbers can be stored at 10 to 12°C for approximately a week, although the shorter the time in storage, the longer the product will last for the consumer. Temperatures below and above these will cause softening and fruit deterioration. Cucumbers also will deteriorate rapidly in the presence of ethylene and should be kept apart from ethylene-producing products such as tomatoes, melons, apples, peaches and other fruit.

Shelf Life

The shelf life of cucumbers depends on the length of time in storage, the storage conditions, and the color and skin type of the fruit. Dark green cultivars last longer than lighter green cultivars. Ribbed fruit lasts longer than smooth-skinned because it is less easily damaged during handling.

Disease Control Recommendations

The recommendations that follow include cultural, biological and chemical control measures as outlined in the most recent issue of the *Guidelines for Plant Disease Control in Western Canada* prepared by the Western Committee on Plant Disease Control. Before using any chemical, carefully read the manufacturer's instructions on the label. All pesticide products registered for use in Canada are licensed by Agriculture Canada. No disease control chemical should be used on any crop for which it is not registered. Such use may pose a threat to consumers of the treated produce and can result in seizure and destruction of the crop by federal inspectors.

Unless otherwise specified, all materials should be applied so as to obtain thorough coverage of the foliage. Applications can be repeated every 7 to 14 days as long as there is a threat of disease spread.

Note: Over a period of time, disease organisms may become resistant or immune to certain pesticides. Therefore, it is advisable to make applications of alternate recommended chemicals where more than one is registered for use against a specific pathogen.

Diseases

Basal Stem Rot and Root Rot

Before planting, sterilize the soil with steam or use a soil fumigant (see Soil Sterilization, page 10). Transplant into a well prepared warm soil (temperature 20°C). Apply a ferbam spray (190-200 g/100 L) and avoid cold water shock as described on page 11 for late damping off.

Black Root Rot

It first appears as a wilting of apparently normal plants during bright sunny weather. Examination of roots of wilted plants reveals that most have disintegrated, and those remaining exhibit tiny black pepper-like dots on the outside and black streaks on the inside. Infected plants seldom die outright but production may be reduced by 50 per cent or more. This disease may occur in sawdust culture.

Control: Avoid introducing the disease by following strict sanitation procedures, including footbaths or overshoes for visitors. Use of new sawdust will usually avoid problems. When using soil or old sawdust, fumigate or steam as for Fusarium root rot and wilt or rotate with tomatoes or graft on resistant *Curcurbita ficifolia* rootstock.

Ensure that soil temperatures are adequate (20°C) before planting. Affected plants can often be saved by mounding the base of the stems with a clean soil-peat mixture, so that new roots are formed. The mound should cover the area of the first leaf scar on the stem.

Cucumber Mosaic Virus

This disease is characterized by irregular patches of yellow on the leaves, especially young ones. These symptoms sometimes disappear at temperatures over 27°C and as infected plants age. Severe stunting of the top growth and undersized, malformed fruits result from heavy infection by some strains of the cucumber mosaic virus (CMV). Most European seedless cucumbers are highly susceptible to CMV.

Control: Plant disease-free seed. Avoid handling infected plants before healthy ones. Disinfect cutting tools and wash hands thoroughly after handling infected plants. Control insects, especially aphids.

Grey Mold

Grey mold is caused by the fungus *Botrytis cinerea*. Characteristic symptoms are tan-colored lesions with or without masses of grey spores. Young fruits, blossoms and pruning wounds are the most common sites of attack. Top growth above stem infections may ultimately die. Grey mold can attack cucumber plants at any stage of their development and is especially serious in greenhouses with poor air circulation and high humidity. Soft, succulent growth produced by excessive application of nitrogen fertilizer is particularly susceptible to grey mold.

Control: Maintain free air circulation around plants and ventilate to reduce humidity. Removing lower leaves will assist air movement. Avoid overcrowding and overfertilizing plants. Pull all weak, dead and severely infected plants and remove all prunings and crop debris from the greenhouse. When pruning, break leaves off close to the stem. Spray stems with a protective fungicide spray soon after pruning or cover the wounds with a thin fungicide paste. Stem infections can sometimes be arrested by scraping them down to healthy tissue and then applying a fungicide paste. The following fungicides are effective against grey mold:

a) Dyrene 50% WP at 200 g/100 L. Do not apply within 1 day of harvest.

b) Ferbam 76% at 200 g or Ferbam 95% WP at 150 g/100 L. Do not apply within 1 day of harvest.

c) Benlate 75 g + Manzate 200, 200 g/100 L. Do not apply within 5 days of harvest.

d) Rovral 50% WP at 100 g/100 L. Do not apply within two days of harvest.

Gummy Stem Blight

The main symptom of this disease is the presence of a gummy, amber-colored ooze, especially at the stem base, followed by wilting and death of the plant. Symptoms usually appear within six weeks after transplanting. Infected areas eventually form dozens of small black fruiting bodies of the causal fungus (*Mycosphaerella citrullina*). Fruits and leaves may also become infected and exhibit similar symptoms.

Control: Plant disease-free seed or treat the seed with captan or thiram. Maintain good ventilation to reduce humidity. Remove dead and dying plants. Once transplanted cucumbers are

established, spray lower stems with one of the following fungicides:

a) Dyrene 50% at 200 g/100 L. Do not apply within 1 day of harvest.

b) Maneb 80% WP at 150 g/100 L. Do not apply within 5 days of harvest.

c) Benlate 50% WP at 50-75 g/100 L in a tank mix with 200-300 g of Dithane M-45 80% WP or Manzate 200. 80% WP. Do not apply within 5 days of harvest.

d) Rovral 50% WP at 100 g/100 L. Do not apply within 2 days of harvest.

High Salts

Plants growing in soils with high levels of soluble salts lack vigorous growth, have small blossoms and scorched or mottled leaves, and generally fail to respond to fertilizer application. A soil analysis should be used to determine salt levels. To correct high salinity, leach soil with water and use fertilizers that do not contribute to the rapid build up of salts (see Fertilizer Section). Avoid using water containing high salt concentration.

Late Damping Off

Use only vigorous transplants that show no sign of disease. Grow seedlings in containers that can be directly transplanted, e.g., peat pots, bottomless plastic pots or rockwool blocks. Make sure the temperature of soil, peat bags or sawdust is 20 to 21°C. Avoid cold water shock to young plants by preheating the irrigation water to 21°C. Immediately after transplanting, spray the base of the plants with Ferbam 76% WP 200 g/100 L of water.

Post-Harvest Breakdown

Under certain conditions seedless cucumbers will deteriorate very quickly after harvest. Several diseases may be involved, including gummy stem blight and scab, especially at the stem end after picking. The breakdown is most frequently seen when several unseasonably cool nights alternate with hot, sunny days in late summer months. It also occurs when storage periods are prolonged after picking, especially at improper temperatures and in poorly ventilized areas. There is no one method of preventing this condition but, especially in summer when you have hot sunny days and below normal temperatures at night, take care to:

a) prevent disease outbreaks

b) avoid water condensation on the cucumbers, i.e., "sweating" by providing a little heat at night

c) avoid overloading, which weakens the plants and causes unhealthy cucumbers that lackturgidity

d) harvest cucumbers with a sharp knife, leaving a 5 mm stem on each fruit

e) avoid tearing, fruit bruises, cuts and abrasions

f) maintain the temperature for marketing and storing at 10-15°C and ideally at 12°C. The relative humidity of the storage area should be between 85 and 95%

g) avoid accumulation of ethylene gas in the storage areas by keeping cucumbers away from apples and other fruits and be sure there's adequate ventilation

Powdery Mildew

The first symptom of this disease is small patches of white powdery growth on the leaves. These spots can quickly spread to cover the whole leaf. Severely affected leaves eventually turn yellow, become brown, and shrivel. Stems and petioles may also become infected, but fruits are rarely attacked. Tiny, spherical brownish-black resting bodies of the causal fungus (*Erysiphe cichoracearum*) may appear on infected leaves as they begin to die. Spider mites often seem to build up faster on plants infected with powdery mildew.

Control: Raise humidity, providing grey mold and other foliage diseases are not prevalent. Practise good sanitation. At the first sign of the diseases, apply fungicide sprays, such as one of the following:

a) Microfine sulphur 92 W at 50-150 g/100 L. Apply weekly to run-off, do not apply within 1 day of harvest.

b) Benlate 50% WP at 50-75 g in a tank mix with 200-300 g/100 L or either Dithane M-45 80% WP or Manzate 200 80% WP. Do not apply within 5 days of harvest. If a serious problem persists, grow powdery mildew resistant cultivars.

Pseudo Yellow Virus

A disease not yet diagnosed in Alberta, but recently reported in Ontario. It is spread by the

greenhouse whitefly. Symptoms are chlorotic yellowing between the veins of older leaves and interveinal yellow spotting on intermediate leaves. Upper foliage may remain unaffected during the early stages. Diseased plants become less productive. There is no know control method except controlling whiteflies. Beets, lettuce and several species of weeds are alternate hosts.

Root Rot and Wilt

Wilt symptoms generally first appear after the stem flush harvest or later. At first, plants may wilt temporarily on sunny days and recover at night, but later they wilt permanently and die. The root systems often look normal; however, internal tissues of the root and stem usually show a slight browning of the vascular (water conducting) tissues. Dead patches of leaf tissue, stunting and poor fruit yield are other symptoms often associated with wilt.

Root rot can attack established plants of any age. Foliage symptoms sometimes resemble those caused by wilt. However, the root systems of affected plants show varying degrees of decay and internal discoloration is usually extensive. Root rot and wilt often occur together in the same greenhouse and sometimes even on the same plant. In Alberta, the fungi causing wilt and root rot include species of *Fusarium, Verticillium, Pythium, Rhizoctonia* and *Acremonium*.

Control: Between crops, treat the soil or rooting media with steam or chemical fumigants. Apply captan or thiram dust to the seed before planting. Rotate cucumbers with non-susceptible crops if practical. Change from soil to a soilless system of growing.

Scab and Leaf Mold

This disease occurs relatively infrequently in Alberta and tends to be restricted to greenhouses with high humidity and a large populations of whiteflies. The insects secrete honeydew on which the scab fungus often grows luxuriantly. Early symptoms on the leaves are water-soaked spots which eventually become tan-colored. Old lesions become papery and soon tear away leaving ragged holes in the leaves. Infected spots on fruits often produce a sticky exudate which dries to a brown bead. As the fruits expand, the spots become cavities which, under humid conditions, are lined with velvety, olive-green spores of the causal fungus, *Cladosporium cucumerinum*.

Control: Reduce humidity by increasing ventilation and raising air temperatures, especially at night. Avoid misting foliage. Practise good sanitation. Spray with Benlate 50% WP at 50-75 g in a tank mix with 200-300 g/100 L or either Dithan M-45 80% or Manzate 200 80% WP. Do not apply within 5 days of harvest.

Sclerotinia Stem and Fruit Rot

Infection usually begins where there is dead or dying tissue, especially wilting flower blossoms or pruning debris. Affected tissue becomes water-soaked and the causal fungus, *Sclerotinia sclerotiorum*, eventually produces abundant white cottony growth and hard black resting bodies called sclerotia. Stem infections usually lead to death of the plant above the point of infection. If infected fruit escapes detection, the disease can spread rapidly in storage.

Control: Maintain free air circulation around plants and reduce humidity. Benlate sprays for powdery mildew and scab will also help to control sclerotinia.

Tip Burn

Adverse environmental factors such as high air temperature, low humidity and high soluble salts appear to be the main cause of the disorder. Leaf margins appear scorched or bleached out. These tissues are a favorite site of attack for the grey mold fungus. Careful attention to fertilization and temperature control will minimize the occurrence of tip burn.

Fruit Curling

Any interruption or slowdown in growth can cause the fruit to curl. Some of the common causes blamed for fruit curling are:

– light fluctuation (from bright to dull)

– excess salts

– moisture fluctuation

– mechanical damage

– fruit resting on stems or petioles

– chilling injury – water condensation damages the skin on one side of fruit

– thrip injury

– gummy stem blight on the fruit

Aborted Fruit

Cucumbers produce far more fruit than they can fully develop. These fruits cease developing either just before or soon after flowering.

This fruit abortion rate may increase periodically when:

– fruit load is high

– light levels decline

– plants have a poor root system

Black Fruit

Very dark green fruit may result from over maturity, or root stress caused by high salts, drying out, or disease. Dark fruit may be hollow on the inside and soft at the flower end.

Light-Colored Fruit

The following factors may contribute to pale colored cucumbers:

– poor light conditions or excessive shading from foliage

– low nitrogen

– varietal differences

– high temperatures

– over maturity

Nutrient Disorders

Mobile elements (first symptoms on older leaves)

Nitrogen

– stunted growth

– lower leaves - yellowish green

– severe cases - entire plant pale green

– younger leaves stop growing

fruit - short, thick, light green, spiny

Remedies:

1. Add calcium nitrate or potassium nitrate.

2. Use a foliar spray of 0.02 to 0.04 per cent solution of urea.

Phosphorus

– stunted plants

– severe cases - young leaves small, stiff, dark green

– older leaves and cotyledons - large water-soaked spots including both veins and interveinal areas

– affected leaves fade, spots turn brown and desiccate, shrivel - except for petiole

Remedies:

Add phosphorus containing soluble fertilizers, e.g., 20-20-20.

Potassium

– older leaves - discolored yellowish green at margins later turn brown and dry

– plant growth - stunted, short internodes, small leaves

– later stages - interveinal and marginal chlorosis extends to centre of leaf, also progresses up plant, leaf margins desiccate, extensive necrosis, larger veins remain green

Remedies:

1. Foliar spray of 0.02 - 0.05 per cent potassium sulphate.

2. Increase the amount of potassium nitrate in your fertilizer program.

3. Check for any antagonism.

Magnesium

– older leaves – interveinal chlorosis from leaf margins inward - necrotic spots develop

– small veins – not green

– severe starvation - symptoms progress from older to younger leaves, entire plant yellows, older leaves shrivel and die

Remedies:

1. Check for possible excess of potassium in your soil. It may be the reason for inadequate uptake of magnesium.

2. Apply 0.02 - 0.05 per cent solution of epsom salts to leaves.

3. If magnesium is lacking in your medium, then add magnesium sulphate.

Zinc

– older leaves - interveinal mottling, symptoms progress from older to younger leaves, no necrosis

– internodes - at top of plant stop growing, leading to upper leaves closely spaced, giving bushy appearance.

Remedies:
1. Foliar spray with 20 - 30 ppm solution of zinc sulphate.

2. Add zinc sulphate to your nutrient solution.
Immobile elements (first symptoms on younger leaves).

Calcium

– upper leaves - white spots near edges and between veins, marginal interveinal chlorosis progresses inward.

–Youngest leaves (growing point region) - remain small, edges deeply incised, curl upwards, later shrivel from edges inwards and growing point dies.

– growth - stunted, short internodes, especially near apex

– buds - abort, finally plant dies back from apex

– older leaves - curve downward

Remedies:
1. In acute cases use a foliar spray of 0.2 per cent calcium nitrate or 0.4 per cent calcium chloride.

2. Add calcium nitrate to your feeding program.

Sulphur

– upper leaves - remain small, bend downwards, pale green to yellow, margins markedly serrate

– plant growth - restricted

– older leaves - very little yellowing

Remedies:
1. Use sulphur containing fertilizer in feeding programs, e.g., potassium sulphate, magnesium sulphate or ammonium sulphate.

Iron

– young leaves – fine pattern of green veins with yellow interveinal tissue, later chlorosis spreads to veins and entire leaves turn lemon-yellow; some necrosis may develop on margins of leaves.

– progression - from top downward

Remedies:
1. In Alberta, it is generally due to highly alkaline pH of soil. Reduce pH using sulphuric or phosphoric acid.

2. For quick recovery, use a foliar spray of 20 to 50 ppm solution of iron chelate once a week for 2 to 3 weeks.

3. On hydroponic culture add iron chelate to your nutrient solution.

Boron

– apex- growing point plus youngest unexpanded leaves curl up and die.

– auxillary shoots - wither and die

– older leaves - cupped upward beginning along margins, stiff, interveinal mottling

– shoot tip - stops growing, leads to stunting

Remedies:
1. Apply a foliar spray of 20 - 30 ppm solution of borax.

2. Add borax to your nutrient solution.

Copper

– young leaves - remain small

– plant growth - restricted, short internodes, bushy plant

– older leaves - interveinal chlorosis in blotches

– progression - leaves turn green to bronze, necrosis, entire leaf withers, chlorosis spreads from older to younger leaves

Remedies:
1. Foliar spray with 10 to 20 ppm solution of copper sulphate to which 0.1 per cent hydrated lime has been added.

2. Add copper sulphate to your feeding program

Manganese

– terminal or young leaves - yellowish interveinal mottling, at first even the small veins remain green, giving a reticular green pattern on a yellow background

– progression - later, all except main veins turn yellow with sunken necrotic spots between the veins

– shoots - stunted, new leaves remain small

– older leaves - turn palest and die first

Remedies:

1. Foliar spray of 20 - 30 ppm solution of manganese sulphate.

2. Add manganese sulphate to your feeding program.

Molybdenum

– older leaves - fade, particularly between veins, later leaves turn pale green, finally yellow and die

– progression - from older leaves up to young leaves, youngest leaves remain green

– plant growth - normal, but flowers are small

Remedies:

1. Foliar spray with 5 to 10 ppm solution of ammonium or sodium molybdate.

2. Add sodium or ammonium molybdate to your feeding program.

Pest Control

Integrated Control

Whiteflies and two-spotted mites on greenhouse cucumbers can be controlled by parasites and predators in conjunction with chemical insecticides. The harmonious use of biological agents and chemicals to control pests is known as integrated control. Chemicals and application methods should be selected to present minimal hazard to the biological agents. Heavily pest-infested areas may require spot treatment, but overall sprays should be avoided. Chemicals applied to control pests other than mites and whiteflies should be selected to be compatible with the biological agents. Chemicals used to decrease pest numbers before introducing biological agents should have little or no residual action.

Insecticidal soap is listed as "harmful, adults (0)," so sprays of this pesticide will only kill adult stages of predators and parasites and it has "0"

Table 9. The effect of greenhouse pesticides on biological control agents

Pesticide	Application	Effect on *E. formosa*	Effect on *P. persimilsi*	Effect on *A. cucumeris*
Ambush	spray	harmful (36)	harmful (30)	harmful (30)
Benomyl	spray	negligible	harmful	harmful
Botran	spray	negligible	negligible	negligible
Bravo	spray	negligible	negligible	negligible
Captan	spray	negligible	negligible	negligible
Diazinon	soil drench	helpful (14)	negligible	harmful (7
Dibrom	fumigant	harmful (7)	harmful (7)	harmful (7)
Dichlorovos	fumigant	harmful (2)	harmful (2)	harmful (2)
Dipel	spray	negligible	negligible	negligible
Insecticidal Soap	spray	harmful (adults)	harmful (0)	harmful (0)
Kelthane	spray	harmful (4)	harmful (14)	harmful (4)
Lannate	spray	harmful (31)	harmful (14)	harmful (14)
Lindane	spray	harmful (14)	harmful (7)	harmful (20)
Malathion	spray	harmful (14)	harmful (14)	harmful (14)
Mancozeb	spray	negligible	negligible	negligible
Maneb	spray	negligible	negligible	negligible
Micro-niasul	spray	negligible	negligible	negligible
Nicotine	fumigant	negligible	negligible	negligible
Parathion	fumigant	harmful (14)	harmful (7)	harmful (7)
Petroleum oil	spray	negligible	harmful (0)	harmful (0)
Rovral	spray	negligible	negligible	negligible
Sevin	spray	harmful (14)	harmful (7)	harmful (7)
Sulphur	dust	negligible	negligible	negligible
Sulphur	fumigant	negligible	negligible	negligible
Tedion	fumigant	negligible	negligible	negligible
Thiodan	spray	harmful (20)	harmful (7)	harmful (7)
Thiodan	drench	harmful (2)	negligible	harmful (2)
Vendex	spray	negligible	negligible	negligible

days residual toxicity so bio-controls could be re-introduced the same day without harm.

Detailed information on using or obtaining the biological control agents can be found by contacting:

Applied Biononmics Ltd.
P.O. Box 2637
Sidney, B.C.
Phone: (604) 656-2123

Insects and Mites

***Whitefly** (Trialeuroides)*

Adults are tiny, white, moth-like insects. They lay eggs on the underside of leaves. In 10-14 days, the larva hatches and undergoes three moults over 14 days to become a pupa, the white scale. The adult emerges in about 6 days. The length of the life cycle is temperature dependent. Adults live 30-40 days and feed by sucking sap from the vascular system.

Control: For Low Populations: Use yellow sticky traps. For tomatoes and peppers use more than 1 trap per 20 plants; for cucumbers use more than 1 per 5 plants.

or

Use *Encarsia formosa* (a parasitic wasp). Traps should be examined weekly. Introductions of *Encarsia formosa* should be initiated within two weeks of the first whitefly being trapped. Place black parasite scales at intervals along the rows. Use 2 to 5 parasited scales per plant per introduction. Introduce parasited scales weekly until 80% of the whitefly scales are parasitized. When the lower leaves bearing parasitized scales must be trimmed off, they should be kept in the greenhouse until the adult parasites have emerged. Do not use Ambush one month prior to introduction of *Encarsia*. (See Integrated Control section.)

For High Populations: Ambush 50EC at 20 ml/100 L. Do not use within one day to harvest.

or

Insecticidal Soap, 1 L/100 L can be applied up to harvest. This reduced rate may be integrated with a parasite vest. This reduced rate may be integrated with a parasite program as it is slightly more toxic to whiteflies than to *Encarsia*.

or

Dibrom EC 10 ml/100 m^3 vaporized from heating pipes. Do not use within 1 day of harvest. May damage flowers.

***Two-Spotted Mites** (Tetranychus)*

The mites are tiny spider-like creatures that feed on plant juices causing leaves to turn yellow and die.

Control: Use *Phytoseiulus persimilis*, a predatory mite. Examine plants regularly for early signs of mite feeding. As soon as the first sign of feeding appears, introduce predators onto the plant at the rate of at least one per infested leaf in the entire greenhouse.

Do not trim leaves off plant. Continue to examine the crop regularly for predators and for two-spotted mites and make further introductions of predators if necessary.

or

Kelthane 18.5 EC at 125 ml/100 L (do not apply within 2 days of harvest).

or

Vendex 50 W at 50 g/100 L. Do not apply to cucumbers within three days of harvest or to tomatoes within five days of harvest.

or

Tedion smoke generators at label rates (do not apply within 1 day of harvest).

Thrips

Adult thrips are tiny insects 0.75 mm long with feathery wings. They develop on weeds and invade the greenhouse, through cracks or vents. Inside the greenhouse, they feed on the undersides of leaves, growing tips and flowers. This feeding results in small, bleached dead spots on the leaf surface, damaged growing tips and flowers. The life history of thrips complicates control attempts because the egg is protected inside the leaf tissue and pupation occurs under ground cover. The eggs are inserted just under the leaf surface by means of saw-like ovipositor. They hatch in about four days into a tiny nymph that feeds for three days before molting to a larger more active stage that feeds for three days more before dropping to the ground to pupate and emerging as an adult two days later. The adult is very active and is attracted to the yellow cucumber flowers. Adult females feed for about 6 days before beginning to lay eggs. They

continue to feed and can lay 50-100 eggs in their 40 days lifetime. Thrips feed much like spider mites by punching and sucking the contents from plant cells, preferring the flowers and lower leaf surfaces. Feeding damage in the narrow crevice between the calyx and the newly forming fruit often results in curled and distorted cucumbers.

Control: Use yellow sticky traps for early detection and monitoring.

Introduce the thrip predator, *Amblesius cucumeris*, on a weekly basis until levels achieve a rate of 100 per plant.

In greenhouses where biological control of whiteflies, thrips or mites is not being carried out, use:

Diazinon 50EC at the rate of 100 ml/100 L to treat 200 m^2 on the soil, not on the plants. This will kill the immature thrips that drop from the leaves to the ground to pupate, as well as the adults that emerge from the soil. Two sprays should be applied: the first as soon as thrip damage is noticed and the second two weeks later. Repeat if the greenhouse is re-invaded by thrips as indicated by dead spots on the leaves.

or

Nicotine smoke, 1 can/300 m^3 (do not apply within 3 days of harvest). May damage flowers of tomatoes and cucumbers.

or

Dibrom EC vaporized from heating-pipes, 10 ml/100 m^3 (do not apply within 1 day of harvest). Apply required amount of Dibrom as thinly and evenly as possible over the pipe surface. Dibrom will often injure flowers of both cucumbers and tomatoes. Do not use higher rates. Keep plants dry for 1 day before treating. On tomatoes, use Dibrom only late in the season when all fruit is set.

Aphids

Aphids are soft-bodied, sucking insects, yellowish-green to black in color, clustered on growing tips of plants or on the underside of lower leaves. They can cause wilting and yellowing of leaves. Aphids excrete honeydew, an ideal medium for growth of fungus. They can also carry and transmit viruses.

Control: Thiodan (skull & crossbones) 4E, 125 ml/100 L or spray (do not apply within 2 days of harvest). Thorough coverage of under sides of leaf is essential for whitefly control.

or

10% Parathion (skull & crossbones) smoke (do not apply within 1 day of harvest). Parathion (skull & crossbones) vapors are extremely poisonous. Use respirator with proper cartridge and ventilate thoroughly before resuming work in the greenhouse. NOTE: Can be very damaging to seedling cucumbers.

or

Insecticidal Soap, 2.5 L/100 L can be applied up to harvest, Insecticidal soap acts only by direct contact so thorough coverage is essential. Phytotoxicity can occur if label rate is exceeded.

or

Nicotine smoke 1 can/300 m^3. Do not apply within 3 days of harvest.

or

Predators - may be used.

(skull & crossbones) Caution, Very Toxic!

Climbing Cutworms and Caterpillars

Dark-colored fleshy worms up to 4 cm long which feed at night. Found during the day in soil. Feed at or below ground level, or may climb and feed on aerial portions of plant. Freshly transplanted succulent plants are especially susceptible. May feed on tomato fruit, producing clean holes on the surface and into the fruit. Caterpillars can be found on the above ground parts of the plant during the day as well as at night; they are nocturnal as are cutworms.

Control: Screen air inlets with 5 mm mesh to keep out adult moths.

or

Thuricide (*Bacillus thuringiensis*) – label rates.

or

Sevin 85 S, 130 g/100 L (do not apply within 3 days of harvest).

or

Parathion (skull & crossbones) smoke fumigators (follow label directions). Do not apply within 1 day of harvest.

Millipedes

Many-legged worm-like insects living within soil and humus piles, where they feed mainly on dead plant material. They can attack living tissue of roots and stems.

Control: See control for sowbugs.

Straw Mites

A creamy white mite introduced to greenhouses on manure or straw. It begins feeding, soon after plants have been set out, on and within the unfolding leaves of the shoot tips. First signs are small perforations on the young leaves. As the leaves grow, the perforations expand into irregular holes, the leaves are distorted and blindness of the growing points may occur.

Control: Parathion smoke fumigators (follow label directions). Do not apply within 1 day of harvest.

Sowbugs

(Also called pill bugs or woodlice). Small many-legged pests living in soilbed during day and feeding on roots and stems at night. The body is segmented, about 12 mm long and 6 mm wide.

Control: Malathion 4% dust, 2.5 kg/100 m^2 before planting. If not controlled, sowbugs can cause damage to young plants.

Slugs

Black or grey slugs 6-12 mm long feed on cucumber and tomato stems and roots.

Control: Use Metaldehyde or bait according to label. Do not apply to edible portions of plants.

Fungus Gnats

The larvae of these small dark grey or black flies are pests of greenhouse plants. Larvae are slender and white with black heads. In cucumber plants they can attack the tap roots and stem cortex near the soil level or larvae can also feed on the root hairs. Affected plants usually grow slowly and some may actually collapse.

Control: Yellow sticky traps for whitefly or thrips may reduce low populations

or

Diazinon 50WP at 50-100 g/100 L. Apply as a soil drench using an adequate volume to wet the growing media.

Springtails

Springtails are the most common insects found in soils. They vary in coloration from white to metallic grey. They commonly range in size from 0.3 to 2 mm. Springtails feed on fungi, bacteria, decaying plant material, pollen and algae but only a few species feed on living plant material. Most springtails are capable of leaping and this is often an aid to identification. All stages are wingless.

Springtails do not appear to cause any economic problems for vegetable growers.

TOMATO PRODUCTION

For general soil and media management, please refer to section on seedless cucumbers. These practices are identical.

Recommended Varieties

There are a number of varieties of tomatoes recommended for production in Alberta greenhouses. Red, large-fruited varieties are the most popular. Dutch seed companies are devoting a major portion of their efforts to develop varieties for Canadian markets. Successful production begins with high yielding, disease resistant varieties. Most varieties carry numbers like "TmC_2VF_1N" with their names. They mean:

Tm = Resistant to Tobacco Mosaic Virus
C_2 = Resistant to race 2 of leaf mold
(*Cladosporium fulvum*)
V = Resistant to *Verticillium*
F_1 = Resistant to *Fusarium*, race 1
N = Nematode resistant

Use these disease resistance criteria to make a suitable selection.

Vendor –Red, ripens uniformly. Fruit size can be very good but because the plant sets fruit very readily, overloading can occur, reducing fruit size. Fertilizing should commence earlier than with other recommended varieties. Vendor is easy to pollinate and is recommended as a spring or fall crop under glass. It can be especially valuable also as a short spring crop under plastic. It is not recommended for growing on Nutrient Film Technique, because the first few trusses overload, resulting in poor development of later trusses. Vendor VFT is now available with tolerance to fungus verticillium, Fusarium I and Tobacco Mosaic Virus. Average fruit weight is 170 g. No green shoulder.

Tropic – Red, large fruited variety. The fruit could be over 250-300 g. Soft fruit may develop during hot weather. Thinning of first trusses to 4-5 fruits/truss is desirable. It is tolerant to *Fusarium*, Race 1 , but not to Verticillium wilt and nematodes. Slight green shoulder is present.

Jumbo – Red, large fruited variety. Green shoulder is present. Tolerant to verticillium, F_2 *Fusarium* and nematodes.

Caruso – It is large fruited with a semi-green back and is the most commonly grown variety in Alberta. It is resistant to tobacco mosaic; *Cladosporium* Race 5, *Verticillium* and *Fusarium* Race 2. Plant growth habit is open and good fruit set under early spring condition.

Larua – Tm C_2 VF_2 variety. Large size, round, semi-green back, slightly ribbed and very firm fruit. Vigorous growth, very compact plant habit. Very well suited for soil, peat bags, rockwool or NFT culture.

Dombito – A large fruited variety; green shouldered with fair tolerance to cracking, F_2 *Fusarium*. Fruit round. Plant has open habit and fruit setting is good.

Cropping Schedules

Late Spring Single Crop

This is the easiest greenhouse tomato crop to produce, and is highly recommended for the inexperienced grower.

Sowing Dates:	December 15 - January 15
Pricking Out:	January 1 - January 30
Planting:	February 15 - February 28
Harvest Begins:	April 20 - May 7
Topping the Plants:	October 15 - October 30
End Crop:	November 15 - December 15

Flowering, fruit setting and fruit growth occur during the increasingly longer and sunnier days of spring and early summer. Harvest can continue into December. Flowers pollinated by October 15 will produce marketable fruits. Growers located at 51 to 53 degrees latitude, should delay schedule by 2 weeks and, at latitudes of 54 to 60, a further delay of 2 weeks is advisable. This schedule is also the most energy conserving and least energy intensive. The main disadvantage is the competition from outdoor grown tomatoes and imports from other countries during August, September and October.

Early Fall Single Crop

Bedding plant growers follow this schedule:

Seed Sowing:	May 1 - May 15
Planting:	June 15 - June 30
Harvest Begins:	August 15 - August 30
End Crop:	October 30 - November 15
Trusses Harvested:	7- 10

A good crop is generally obtained on this schedule. Good sanitation practices are required to control insect and diseases, carried over from bedding plants.

The Two-Crop System

A rigid disease control program is a must for the success of this system. Essentially a spring and a fall crop are produced.

1. Spring Crop

Seeded:	November - mid-January
Planted:	mid-January - mid-March
Harvest Begins:	Late March - mid-May
Crop Pulled:	July

Normally, 10 to 15 clusters of fruit should be harvested.

2. Fall Crop

Seeded:	June 15 - July 1
Planted:	mid-August
Harvest Begins:	October
Topping:	late October
Crop Pulled:	December - January
Trusses Harvested:	7 - 10

Raising Healthy Transplants

Most greenhouse operators in Alberta grow their own transplants. Much of the success of a crop depends upon the attention paid to details and the care extended during plant raising. Moreover, in the case of early spring crops the transplants are raised in the winter when natural light is limiting. To make the best use of available light, other factors such as spacing, temperature, watering and nutrition must be subject to close and accurate control. Artificial light is now widely used to enhance transplant growth.

Propagation Schedules

In deciding when to seed the following factors should be considered:

(i) it generally takes 90 to 120 days from seeding to harvest in spring crops

(ii) the time will be 80 to 100 days in the case of the crops seeded in May - June

(iii) A seedling is ready for planting in the greenhouse within 40 to 50 days.

Seed Sowing

There are about 300 seeds per gram. Assuming a planting density of 25,000 plants per hectare, a germination rate of 80 percent and a safety margin of an additional 10 per cent of plants, one can easily calculate the amount of seed to be sown at approximately 120 g per ha.

The most common approach is to broadcast seed or to sow it in rows in trays (55 x 27 cm) filled with a soilless mix (e.g., commercial peat mixes). The tray (usually plastic) is first filled with the growth medium, struck off level and the medium pressed down evenly (with a wooden board) to about 1.5 cm from the top.

It is also useful to soak the filled tray and allow it to drain before sowing. Sowing is done as evenly as possible, at the rate of 500 to 600 seeds per tray.

The seed is covered with 0.5 cm of growth medium (fine grade) to assist in prompt shedding of the seed coats, thus reducing the risk of transmitting tomato mosaic virus and of distorting the seed leaves.

After sowing, seed trays are covered with glass or paper, which conserves moisture and no further watering is needed before germination.

The seed trays are placed in a small greenhouse or special propagation room (no light is needed at this stage) at 24°C (day and night) until daily inspection shows seedlings to be breaking the surface of the growth medium.

The higher the air temperature of the propagation room during germination, the faster and more uniform the germination will be. However, seedling growth is fast at high temperatures and this makes the use of a high germination temperature risky because a delay of a few hours in removing the seed tray cover can result in excessive seedling stem elongation and carbohydrate depletion.

Once seedling emergence is well under way, the seed tray covers are removed and the air temperature is reduced to 20°C (day and night), and as much light as possible is supplied. These conditions are maintained for two to three days to allow all seedlings to emerge and become photosynthetically active and to prevent excessive elongation.

The Cold Treatment

Cold treatment subjects young tomato seedlings, just after the seed leaves (cotyledons) unfold and the first true leaves start to appear (figure 7), to 10° to 13°C (night/day) air temperature for approximately two weeks, while providing as much light as possible for nine to 12 hours.

Low shoot temperatures at this stage of growth result in a small number of leaves below the first cluster (and therefore earlier flowering), whereas low root temperatures result in branched clusters (many flowers in the first and possible the second cluster).

Cold temperatures during both day and night are effective. The cold treatment increases the number of flowers, but does not influence the setting of fruit. If later conditions for fruit setting are right, then a greater number of flowers will set fruit due to the increased number of blossoms.

If, however, temperature for fruit set remains sub-optimal, then the pollen will not germinate and grow normally and this will result in poor fruit set and cat-faced fruit.

When the cold treatment is to be used, sowing should take place 10 to 14 days earlier than usual to compensate for the very slow growth rate during the cold treatment. The growth medium in the seedling trays must be sterile, because when plants are grown at relatively low temperature the danger of damping-off is increased.

Transplanting into Pots (Pricking Out)

Experience dictates that the best time to prick out tomato seedlings is at cotyledon expansion, just after the cold treatment. Any earlier than this seedlings are too hard to handle, and any later the transplanting shock will be greater due to more roots being broken.

Transplants are grown in 7.5 cm (3 in.) or 10.0 cm (4 in.) plastic pots or in soil blocks. In addition to good top soil, peat mixes are extensively used as growth media but always after proper sterilization. The most practical approach is to use an established mix which is known to give good reliable results.

Growers should avoid carrying out their own modifications to recommended mixtures as the results could be disastrous.

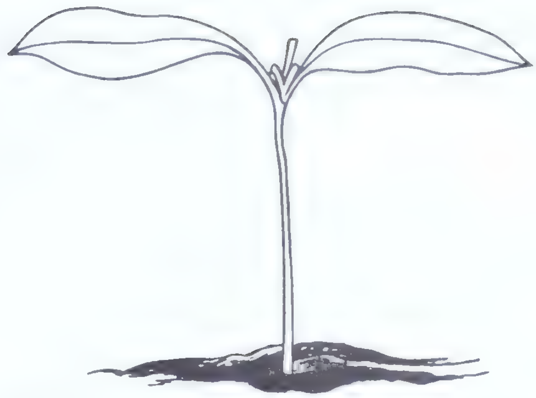

Figure 6. The growth stage at which tomato seedlings should be transplanted.

There has been a world-wide trend towards peat-based mixtures to replace those containing loam, due to difficulties in obtaining loam of desirable specifications. However, when the greenhouse soil is of good texture and structure it is a valuable asset as a growth medium for transplant raising, provided it is effectively sterilized before use.

Heavy leaching following soil sterilization is also highly recommended. This treatment ensures the removal of excessive salt which can be harmful to young seedlings but also results in low nutrient levels (especially nitrogen) in the growth medium, allowing for better plant growth control through liquid feeding manipulation.

Water and Nutrition of Transplants

The aim should be to keep the young plants well supplied with water without depleting the growth medium of its oxygen by over-watering.

Transplants raised in 10 cm pots will require watering daily in good weather and, occasionally in very bright weather, more than one watering a day may be necessary. In dull winter weather, watering as infrequently as once every three days may be adequate.

A deliberate short water supply in the propagation pots restricts growth and has helped in the past produce stocky dark green, hardy plants. However, this type of growth control invariably results in excessive hardening of the transplants due to the difficulties in regulating the water supply and this results in yield losses early in the production season when prices are best. In

recent years, more dependable means of growth control have been identified through research.

Continuous feeding of fertilizer at every watering is now practised and the fertilizer concentration in the solution is used as an osmoticum in regulating water availability to the plants.

The recommended fertilizer concentration in the irrigation water, measured as its electrical conductivity (EC), varies according to the environmental conditions. For transplant raising during the winter months a complete nutrient solution of an EC ranging between 3 to 6 millisiemens cm^{-1} has been used with good results. There are indications that the higher conductivities are safer when the K:N ratio in the nutrient solution is higher than 4:1.

Also, the supply of artificial lighting allows the use of higher EC than normal but not when artificial lighting results in overheating of the transplants and drier conditions in the greenhouse.

Transplants of similarly good quality can also be raised when commercial mixes of fertilizer such as those commonly known as "starters" are used at appropriate rates. A simple solution of "starter fertilizer" (1 g of 10-52-10 per litre of water) with an approximate EC of 1.5 millisiemens cm^{-1} used in continuous feeding produces transplants acceptable to most growers in a simple and safe way. Alternatively, the commercial fertilizer mix Hydrosol, which contains all nutrients except Ca and which offers K/N ratio of about 5:1 can safely be used with acceptable results at an EC up to 4 millisiemens cm^{-1}

Artificial Lighting of Transplants

Artificial lighting, as mentioned earlier, is first used immediately after germination. A relatively small installation is needed at this stage and high light intensities are economically feasible. Both fluorescent and high pressure sodium (HPS) lamps are acceptable and are widely used to generate a minimum light intensity of 100 umole $s^{-1}m^{-2}$ (equivalent to 20 Wm^{-2} or 8,000 Lux or 760 fc) in growing rooms.

The fluorescent lights produce slightly shorter plants with a deeper green-bluish color than the HPS lamps, but the HPS lamps are the most economic to install and operate. During the first few days after pricking out, when the pots can be arranged close together, it is still economical to maintain high light intensity (75 to 100 umole $S^{-1}M^{-2}$) for approximately 16 to 18 hours daily.

However, as plants grow they are progressively spaced to avoid crowding and becoming spindly, making the use of high light intensities less and less cost effective. For the most part, while plants are at the propagation house, supplemental lighting (artificial lighting in addition to natural light) is provided at an intensity of 50 umole $s^{-1}m^{-2}$ (equivalent to 10 w m^{-2} or 4,000 Lux or 380 fc).

Obviously, whenever cost is not a factor, the highest light intensity available should be provided for a maximum of 18 hours daily as this treatment will result in shorter propagation time and heavier, stronger, sturdier transplants. There is no advantage in using low intensity incandescent lighting on tomato plants in mid-winter to extend the daylight period.

Temperature Control

The recommended temperatures for transplant raising along with those mentioned earlier for seed germination and the cold treatment are summarized in table 10.

Carbon Dioxide Enrichment

An enriched atmosphere with carbon dioxide (CO_2) at a nominal concentration of 1,000 vpm (ppm) during propagation increases plant vigor and early fruit set and may partially compensate for poor light conditions. The beneficial effects of CO_2 enrichment are more evident when air temperatures are on the high side and proportional to the duration of enrichment.

The application of CO_2 should coincide with the day period including any part of the night when artificial light is supplied. Considering the small area involved in transplant raising it is economically feasible and highly advisable to use liquid CO_2 (CO_2 gas liquified under pressure) as the source of CO_2 because of its guaranteed purity and the convenience in its supply control and because of the high risk for plant injury from gaseous pollutants when CO_2 is generated by burning natural gas or propane in a well sealed environment.

Table 10. Recommended temperatures for tomato transplant raising.

Growth Stage	Light Conditions	Air Temperature in °C Day	Night
Seed Germination	Not critical	24°	24°
For two weeks after colyledon expansion (i.e. cold treatment)	Maximum available light intensity for 9-12 hrs. daily	10-13°	10-13°
After pricking out (i.e. while in pots)	Good light conditions	21°*	18°
After pricking out (i.e. while in pots)	Poor light conditions	19°	17°

* When cold tolerant cultivars (e.g. cv. Vendor) are grown, air temperatures can be lower by 1-2 C than those indicated. However, when vigourous cultivars such as Caruso, Dombioto or Laura are grown, a similar reduction in air temperature will result in poor quality (cat-faced) fruit.

Grafting

Grafting is a useful technique where soil sterilization is not available or even against diseases not controlled by soil steaming (e.g. fusarium crown and root rot). Wild species that are closely related to the tomato or even tomato cultivars which have resistance to a number of diseases are used as rootstocks.

At present, rootstocks are available with resistance to corky root rot, fusarium and verticillium wilt, root knot nematode and fusarium crown and root rot. There are a number of grafting methods suitable for tomatoes, but their description is beyond the scope of this book.

Management of Seedlings in Rockwool

Hydroponic growers use 10 cm rockwool blocks for direct seeding. Temperature regimes are as mentioned before.

The seedlings grown on such materials, need constant complete fertilization after expansion of the first true leaves and regular pH adjustments. The electrical conductivity of nutrient solution can be increased to 4-6 millisiemens under low light conditions. If additional lights are used, then lower conductivities (2-3 millisiemens) should be used.

The following fertilizer formula has been successfully used:

Calcium nitrate	50 g/100 L
Potassium nitrate	50 g
Potassium sulfate	30 g
Magnesium sulfate	25 g
Micronutrients	8 g
Phosphoric acid	10 ml

Commercially available hydroponic mixes can also be used. Increase EC by raising the quantity of Potassium sulfate.

Chemical Treatments

Chemicals may either retard or stimulate tomato flowering. Those such as N-m-tolyphthalamic acid (Duraset-20W) applied to young seedlings during the sensitive period (10-14 days following cotyledon expansion) may increase flower numbers several fold. "Auxins" generally increase flower numbers and may induce tomato plants to flower earlier. "CCC" accelerates flowering by reducing the time to the first open flower; fewer leaves are formed before the first flower cluster. Gibberellin decreases flower numbers, and elongates the styles of the flowers so that the stigma may extend beyond the stamen cones. It may promote anther development and pollen production in otherwise male sterile types. Maleic hydrazide and "phosphon" compounds also delay flowering.

There is no relationship between chemical growth promotion or inhibition in the tomato plant and flower formation. No chemical effects are as reproducible as those of temperature, light, carbon dioxide, or nutrient level. The use of chemicals to regulate tomato flowering is not recommended.

Plant Density

A final plant density of 210 to 270 plants per 100 m^2 is recommended. Early crop tomatoes should be grown at lower densities to maximize light and yields.

Planting Out

When pots are placed out at final spacing for an early crop, they should be placed on the media but not allowed to root out. Use a small piece of plastic under the pot to accomplish this. Plants can be tied up at this time, anchoring the string under the pots. Allow plants to set one truss before rooting out. Continue to maintain high EC in the root zone (3.5-5.0) until light levels improve or fruit begins to size.

Crops seeded after mid-December can be planted directly into the media. One drip tube can be placed at each plant and double strength fertilizer (E.C. 3.5) (do not increase the concentration of minor elements) used until plants are allowed to root into the sawdust.

Pollination

Temperatures (minimum night temperature 16°C) play an important role in pollen development and in shedding of the pollen. Pollen is shed more abundantly on bright sunny days when temperatures exceed 20°C. Pollination is best carried out at mid-day every other day. Pollination should continue for the entire crop life.

Pollinate flowers by means of an electric vibrator.

Adequate air movement in the house with tomatoes is desirable.

Training

Greenhouse tomatoes are usually trained to a single stem, by removing the lateral shoots before they are 5 cm long and while they can be snapped off by hand. Support them by attaching one end of a plastic twine to the base of the stem by means of a non-slip loop; fasten the other end to an overhead wire running the length of the row at a height of 2-2.5 m. To support the stem as it grows, wind the twine around the plant in one or two spirals for each truss.

Plastic clips may be used as an alternative to the usual twisting method. The clip is snapped together by placing the hinge area on the supporting twine and the loop position around the plant.

The growing tip of tomato plants should be pruned approximately 45 days for the spring crop and 55 to 60 days for the fall crop before to the end of the harvest period.

Fertilizing Soil Grown Crops

A schedule for the weekly application of fertilizers is given below. To estimate the fertilizer needs of the crop, the growth should be carefully watched and tissue and soil tests should be made periodically. No formula can take the place of good judgement. The schedule should be used only as a guide and should be adjusted to suit the fertility level and the progress of the crop in each greenhouse.

Caution: Choose soluble fertilizer formulations that are as free as possible of chlorides, sulphates and carbonates.

Spring crop, low fertility soil, most tomato varieties - follow schedule unchanged.

Spring crop, low fertility soil, variety Vendor and similar early setting varieties - omit weeks 3 and 4, proceed immediately to week 5 after week 2.

Fall crop, tomato - weeks 2, 3 and 4, proceed immediately to week 5 after week 1.

High fertility soil - apply fertilizer at one-half the recommended rate until mid-season.

Soilless culture - use 10-52-17 and 20-5-30 with added trace elements.

For 10-52-17 - can substitute 10-52-10 or 9-45-15.

For 20-5-30 - can substitute 20-20-20- and increase potassium nitrate.

Liquid Fertilizers for Tomatoes

Standard liquid fertilizers – Three standard liquid feeds are recommended for tomatoes:

- High Potash - where extra control over growth is required
- Medium Potash - used as the main feed
- High Nitrogen - when extra vigor is required

These feeds are based on potassium nitrate to which may be added urea or ammonium nitrate in order to adjust the ratio of nitrogen (N) to potash

Table 11. Guide to weekly Application of Fertilizer.

Week after Transplanting	10-52-17	20-5-30	KNO_3 potassium nitrate	$Ca(NO_3)_2$ calcium nitrate	NH_4NO_3 ammonium nitrate	$MgSO_4$ magnesium sulphate
1	1.0					
2	0.5					
3	0.5					
4	1.0					1
5		1	0.5	0.5		
6		1	0.5			1
7		1	0.5	1		
8		1	0.5			1
9		1	1	1		
10		1	1			
11		1	1	1		1
12		1	1			
13		1	1	1		
14		1	1		0.5	1
15		1	1	1		
16		1	1		0.5	
17		1	1	1		1
18		1	1		0.5	
19		1	1	1		
20		1	1		0.5	1
21		1	1	1		
22		1	1		0.5	
23		1	1	1		
24		1.5				
25		1.5				

Table 12. Standard liquid fertilizers for soil based crops

Feed	Feed Ratio $N:P_2O_5:K_2O$	ppm in dilute solution (1 in 200) $N:P_2O_5:K_2O$	Fertilizer	Weight of fertilizer for stock solution of: 10 gal lb	10 gal kg	40 gal lb	40 gal kg
High Potash	1:0:3	145:0:505	Potassium Nitrate	22	10	90	40
Medium Potash (Using Urea)	1:0:2	175:0:350	Potassium Nitrate	15.75	7	63	28
			Urea	3.25	1.5	13	6
			Magnesium Sulphate	3.5	1.5	14	6
Medium Potash (Using Ammonium Nitrate)	1:0:2	175:0:350	Potassium Nitrate	15 .75	7	63	28
			Ammonium Nitrate	4	2	17	8
			Magnesium Sulphate	2	1	10	4
High Nitrogen (Using Urea)	1:0:1	250:0:250	Potassium Nitrate	11	5	45	20
			Urea	7	3.5	30	14
			Magnesium Sulphate	3.75	1.75	15	7
High Nitrogen (Using Ammonium Nitrate)	1:0:1	250:0:250	Potassium Nitrate	11	5	45	20
			Ammonium Nitrate	10	4.5	40	18
			Magnesium Sulphate	1	0.5	5	2

Table 13. Liquid fertilizers containing phosphate

Feed	Feed Ratio $N:P_2O_5:K_2O$	ppm in dilute solution (1 in 200) $N:P_2O_5:K_2O$	Fertilizer	Weight of fertilizer for stock solution of: 10 gal lb	10 gal kg	40 gal lb	40 gal kg
High Potash	1:1:2	170:170:450	Potassium Nitrate	20	9	80	36
			M.A.P. *	5.75	2.6	23	11
Medium Potash (Using Urea)	1:1/2:2	175:85:350	Potassium Nitrate	15.75	7	63	28
			M.A.P.	2.75	1.2	11	5
			Urea	2	1	10	4
Medium Potash (Using Ammonium Nitrate)	1:1:2	175:85:350	Potassium Nitrate	15.75	7	63	28
			M.A.P.	2.75	1.2	11	5
			Ammonium Nitrate	3	1.5	13	6
Medium Potash (Using Urea)	1:1:2	175:175:350	Potassium Nitrate	15.75	7	63	28
			M.A.P.	6	2.7	24	11
			Urea	1.75	0.8	7	3
Medium Potash (Using Ammonium Nitrate)	1:1:2	175:175:350	Potassium Nitrate	15.75	7	63	28
			M.A.P.	6	2.7	24	11
			Ammonium Nitrate	2	1	10	4
High Nitrogen (Using Urea	1:1:1	250:250:250	Potassium Nitrate	11	5	45	20
			M.A.P.	8	3.9	34	15
			Urea	5	2.3	20	9
High Nitrogen (Using Ammonium Nitrate)	1:1:1	250:250:250	Potassium Nitrate	11	5	45	20
			M.A.P.	8	3.9	34	15
			Ammonium Nitrate	7	3.3	28	13

* Mono-Ammonium Phosphate

(K_2O) as required by the crop. Magnesium sulphate is added to these feed to provide 10-30 ppm magnesium (as MgO) in the dilute feed. Urea or ammonium nitrate should be used only in high light periods — between April to September, and in soil or peat-based culture. For Nutrient Film Technique, urea or ammonium nitrate should not be used.

Liquid fertilizers containing phosphate – Liquid fertilizers with phosphate are often recommended for tomatoes grown in soilless substrates. Mono-ammonium phosphate 11-48-0 is added to the standard feeds but **omitting** magnesium sulphate.

Liquid fertilizers containing calcium – These feeds may be required in certain circumstances and are prepared by adding calcium nitrate to the standard feeds. Both magnesium sulphate and mono-ammonium phosphate **must be absent** from feeds containing calcium and all storage vessels and lines.

Important: Liquid fertilizers containing calcium and phosphate should not be mixed together as this leads to the formation of insoluble calcium phosphate which, apart from making both phosphate and calcium less available to the plants, results in severe blocking of the nozzles and lines of the irrigation system. Magnesium sulphate is also omitted from both phosphate and calcium feeds for similar reasons.

In the tables, the weights of material used are given as pounds (lb) or kilograms (kg) to be dissolved in the appropriate volume of solution (gallons). This stock solution is then diluted 1 in 200 for use.

Table 14. Liquid fertilizers containing calcium

Feed	Feed Ratio $N:P_2O_5:K_2O$	ppm in dilute solution (1 in 200) $N:P_2O_5:K_2O$	Fertilizer	Weight of fertilizer for stock solution of: 10 gal lb	10 gal kg	40 gal lb	40 gal kg
Medium Potash (Using Urea)	1:0:2	175:0:350	Potassium Nitrate	15.75	7	63	28
			Calcium Nitrate	6	3	26	12
			Urea	1	0.5	4	2
Medium Potash (Using Ammonium Nitrate)	1:0:2	175:0:350	Potassium Nitrate	15.75	7	63	28
			Calcium Nitrate	6	3	26	12
			Ammonium Nitrate	1	0.5	4	2
High Nitrogen (Using Urea)	1:0:1	250:0:250	Potassium Nitrate	11	5	45	20
			Calcium Nitrate	6	3	26	12
			Urea	5	2.5	22	10
High Nitrogen (Using Ammonium Nitrate)	1:0:1	250:0:250	Potassium Nitrate	11	5	45	20
			Calcium Nitrate	6	3	26	12
			Ammonium Nitrate	7	3.2	30	13

These fertilizers provide 100 ppm calcium (as CaO in the dilute feed).

Feed		Fertilizer	10 gal lb	10 gal kg	40 gal lb	40 gal kg
High Calcium	A special purpose feed used to correct calcium deficiency.	Potassium Nitrate	8	3.5	32	14
		Calcium Nitrate	10	4.5	40	18
Contains:	250 ppm N 250 ppm K_2O 300 ppm CaO Dilute at 1 in 100					

Storage

Nitrate fertilizers increase the fire and explosion risks when mixed with combustible materials. Store away from organic materials, grease, dust, excessive heat or flames.

All solid fertilizers should be stored in dry, well-ventilated conditions. Prepared mixtures should be kept in closed containers such as polyethylene bins or sacks and used as soon as possible.

Mixing

All the solid fertilizers must be completely and evenly dissolved in the appropriate volume of solution. The following rules will ensure this.

Keep the Solution Warm- Using hot water helps to speed up the dissolving process.

Stir Thoroughly - This is necessary even though the fertilizer appears to have dissolved.

Keep Stock Solution in a Warm Place - This will prevent crystal formation which can cause faulty dilution.

Note: It is helpful to have two barrels of stock so that one is always ready for use.

If, for any reason, it is not possible to dissolve the fertilizer completely, a half-strength stock solution used at twice the normal dilution rate could be used.

Dilutors

Cleaning - All dilution and ancillary equipment should be serviced regularly in order to ensure that they are functioning correctly. Nozzles, jets, valves, capillary lines, barrels and tanks should be inspected from time to time during the season, drained and washed out to remove sand, silt and any other insoluble materials. Sand filters need to be washed according to instructions and wire gauze filters need frequent inspection and cleaning.

Table 15. A suggested irrigation program for an early spring crop of greenhouse tomatoes

Week	Number of applications	Litres/ plant	cm/ week
March 23-27	1	9.0	1.9
March 30-April 3	1	4.5	1.9
April 6-10	1	4.5	1.9
April 3-17	2	9.0	1.9
April 20-24	2	9.0	1.9
April 27-May 1	3	14.0	2.8
May 4-8	3	20.0	4.7
May 11-15	3	20.0	4.7
May 18-22	3	25.0	5.6
May 25-29	3	25.0	5.6
June 1-5	3	25.0	5.6
June 8-12	3	25.0	5.6
June 15-19	3	25.0	5.6
June 22-26	3	25.0	5.6
June 29-July 3	3	25.0	5.6
July 6-10	3	25.0	5.6
July 13-17	3	25.0	5.6
July 18-22	3	25.0	5.6
July 23-27	3	25.0	5.6
July 28-August 1	3	25.0	5.6
August 2-6	3	25.0	5.6
August 7-11	3	25.0	5.6
August 12-16	3	25.0	5.6
August 17-21	3	25.0	5.6
August 22-26	3	25.0	5.6
August 27-31	3	25.0	5.6
September 1-4	2	20.0	4.7
September 5-9	2	20.0	4.7
September 10-14	2	20.0	2.8

Table 16. Tomato feeding formula for sawdust culture

	Concentration (ppm)	for 1000 L grams	millimol/L
Calcium nitrate (15.5-0-0)	118 N	760	NO_3 -13.5
(19% Ca)	144 Ca		H_2PO_4 - 2.0
Potassium nitrate	72 N	550	K - 7.0
(13-0-46)	210 K		Ca - 3.5
Magnesium sulphate	25 Mg	250	Mg - 1.0
	64 S		SO_4 1.0
Monopotassium phosphate	64 P	280	
(0-53-34)	79 K		

Minor Elements	Concentration (ppm)	for 1000 L grams	micromol/L
Iron chelate (10% Fe)	1.5 Fe	15	Fe - 25.0
Manganese sulphate (28% Mn)	0.5 Mn	1.78	Mn - 9.0
Solubor (20.5% B)	0.5 B	2.43	B - 46.0
Zinc sulphate (36% Zn)	0.1 Zn	0.280	Zn - 1.5
Copper sulphate (25% Cu)	.03 Cu	0.120	Cu - 0.5
Sodium Molybdate (39% Mo)	.05 Mo	0.128	Mo - 0.5

Checking - Dilutors should be checked for accuracy at the start of the season and thereafter every 2 months or so. Samples of both stock and dilute solution can be submitted to the Alberta Special Crops and Horticulture Research Center for a conductivity check.

Preparation of Dilute Solutions (direct)

When preparing dilute solutions in a tank or reservoir the fertilizer should be pre-mixed in a smaller volume of water (as for a stock solution). This solution can then be added to the storage vessel at the appropriate rate and thoroughly mixed for use.

Once plants have rooted into the media, the fertilizer concentration can be lowered to an EC of 2.5-3.0 in the root zone for the duration of cropping. Beef type varieties have a high requirement for potassium, especially as fruit load increases. Two weeks before picking, increase potassium levels by 20% and continue until picking starts. This is also important for fruit quality. Fertilize plants in sawdust culture regularly, at least once per hour in bright weather. Feed volume may start at 400 ml per plant per day and progress with growth and weather to as much as 3000 ml per day. Allow for 10-20 per cent leaching to control the accumulation of soluble salts. A feeding solution temperature of 20°C is desirable.

Temperatures

Night 17 - 18°C
Day 18 - 21°C
Vent + 0.5 - 2.0°C

The average 24 hour temperature is responsible for the rate of growth (the higher the average the more rapid the growth).

The temperature level is responsible for the form of the plant (the larger the variation in day/night temperature the taller the plant and smaller the leaf size).

Truss Pruning

Truss pruning is recommended to increase the size of the fruit and balance the fruit load on the plants. For large fruited varieties like Dombito, prune the first 2-3 trusses to 3 marketable fruit. Later trusses prune to 4 fruit. Remove fruit before they start to size and remove all other flowers once the desired numbers of fruit are set.

Fruit Harvest

All fruit must be at least green mature when harvested. It is preferable to harvest tomatoes at color break. This is indicated by a yellow orange coloration beginning at the blossom end of the fruit. With most varieties, harvesting begins 5 to 7 weeks after the fruit has set, earlier in summer, later when sunlight conditions are less.

Careful handling of tomato fruits during harvesting will increase their shelf life. If fruit is picked with more color, the tomatoes must be handled more carefully by:

– minimizing drop heights

– using soft materials in picking boxes

– harvesting early in the morning when fruit temperatures are low

– cleaning picking boxes and grading machines regularly.

Accelerated Ripening

Ethephon (Ethrel) treatment is useful for hastening fruit maturity and shortening the harvest period. It should only be used when cleaning up a crop at the end of the season because severe plant injury may occur with the treatment. Ethephon will not ripen immature green fruit.

Note: Ethrel treated fruit may not be suitable for marketing through regular channels because the accelerated ripening will result in a shorter storage life for the fruit. This problem will be more pronounced during hot weather.

Mix 375 ml of Ethephon per 100 litres of water and spray uniformly over foliage and fruit. When average greenhouse temperatures are below 18°C, use the higher application rate. Harvest fruit at proper maturity, generally 10 to 21 days after treatment.

Note: Spray plants immediately after a harvest so as to allow the maximum time from treatment to harvest. Do not apply when greenhouse temperatures exceed 38°C.

Harvesting, Handling and Marketing

Optimal color development occurs at 16 to 22°C. Tomatoes produced by the nutrient film culture technique have been noted to ripen more

uniformly, are slightly firmer and less "boxy" than those grown in peat culture. Greenhouse tomatoes should be harvested only after they have begun to ripen on the vine.

Harvest requires hand labor and personal selection of each fruit.

Harvested tomatoes should be removed from the greenhouse as soon as possible. This is particularly critical during the months of May, June and July for the spring crops, September and October for all crops. When these fruits are left in the greenhouse area, the internal fruit temperature plus the heat of respiration in a stacked lot of containers can result in a rapid breakdown of the harvested tomatoes. Harvest tomatoes as early in the day as possible so as to have the lowest possible internal temperature.

Following harvest, tomatoes may be held for a few days at 15.5 to 18°C for ripening if not in full color, and for short intervals at 10 to 13°C if fully ripe. Tomatoes should not be held in cold storage. It is important that the fruit be moved rapidly through marketing channels.

Greenhouse Labor Breakdown

Activity	% of total labor
Pruning and tying	35
– pollinating	10
– planting	2
Chemial and fertilizer preparation	3
Disease and insect control	3
– harvesting	25
– packing	10
– delivery	8
Maintenance and sanitation	4

Yields

Progressive greenhouse tomato growers now accept that a profitable production program should aim at 40 kg/m^2 or more of marketable tomatoes. Experimentally, yields of up to 44 kg/m^2 have been achieved. Fifty kg/m^2 yields have been reported from places like Saudi Arabia, where light is not a limiting factor.

Disease Control Recommendations

The recommendations which follow include cultural, biological and chemical control measures as outlined in the most recent issue of the *Guidelines for Plant Disease Control in Western Canada* prepared by the Western Committee on Plant Disease Control. Before using any chemical, carefully read the manufacturer's instructions on the label. All pesticide products registered for use in Canada are licensed by Agriculture Canada. No disease control chemical should be used on any crop for which it is not registered. Such use may pose a threat to consumers of the treated produce and can result in seizure and destruction of the crop by federal inspectors.

The amounts of disease control materials specified in this section are for 100 litres of water.

Unless otherwise specified, all materials should be applied so as to obtain thorough coverage of the foliage. Applications can be repeated every 7 to 14 days as long as there is a threat of disease spread. Preharvest intervals (number of days which must elapse between treatment and harvest) are specified after each chemical mentioned.

Note: Over a period of time, disease organisms may become resistant or immune to certain pesticides. Therefore, it is advisable to make alternate applications of recommended chemicals where more than one is registered for use against a specific disease.

Diseases

Bacterial Canker

Wilting of leaflets is the first symptom of bacterial canker on plants regardless of their age. The margins of the leaflets usually wilt first, turn brown, and die progressively from the margins toward the midrib. Sometimes only the leaflets on one side of the leaf are affected. Light-colored streaks extending up and down the outside of the stem and on the petoile may accompany wilting of the leaves. These streaks sometimes break open to form a canker. As the disease progresses, the stem pith becomes yellow and mealy, and cavities may form therein. Severely affected plants usually die. If the crop is watered by overhead sprinklers, small "birds's eye" cankers may form on the fruit. Bacterial canker is caused by *Corynebacterium michiganense.*

Control: Sow only hot-water-treated seed. For hot water treatment of seed of doubtful status, place seed in a loose cheese cloth bag and soak in water at 50°C for 30 minutes. Treatment at 53°C may be carried out if the seed is planted within a

few days. Use an accurate thermometer and keep the seed agitated during treatment. Spread seed out to dry immediately after treatment. Also, follow a rigid schedule of sanitation throughout the season. Steam or chemically fumigate all soil, flats, pots, etc. in which seedlings are grown. Rogue out and destroy all infected plants. After handling diseased plants, wash hands thoroughly with soap and water. Apply protective sprays of copper oxychloride 200-400 g/100 L or water at 7 day intervals – 1 day.

Blossom-end Rot

This is a non-infectious disease caused by water stress and calcium deficiency. If rapidly growing plants are suddenly exposed to drought, insufficient water enters the plant and a brownish, sunken decay of the blossom-end of the fruit may occur. Occasionally, secondary organisms invade this tissue and produce a soft rot.

Control: Maintain a steady rate of plant growth. Avoid wide fluctuations in soil water, soil compaction and air temperature. Keep soil test calcium levels over 200 ppm. Apply calcium chloride at 5.0 kg/1000 L of water as a foliar spray at the first sign of blossom-end rot.

Damping-off (See page 11)

Early Blight

The first symptoms of early blight usually seen are circular, dark brown to black spots of various sizes on the leaves. As the spots enlarge, concentric ridges ("target spots") often form on their upper surface. On the stalks, branches and fruit pedicels, early blight appears as black lesions that subsequently enlarge and elongate, and sometimes girdle the infected plant parts. On the fruit, infection results in large, black, leathery, sunken lesions. Under humid conditions, spores of the causal fungus, *Alternaria solani,* may form on lesion surfaces.

Control: Avoid prolonged periods of high humidity. Practise good sanitation. Apply protective sprays using the following fungicides:

– Dyrene 50% WP at 200 g- 1 day, or

– Benlate 50% WP at 100 g in a tank mix with 200 g of either Dythane M-45 or Manzate 200 - 1 day, or

– Zineb 75% WP at 200 g - 1 day, or

– Dithane M-45 80% WP or Manzate 200 80% WP at 200 g - 1 day.

Grey Mold

Infection usually occurs on dying tissue at the base of leaf petioles, on pruning wounds and on blossom or stem end of fruits. Under favorable conditions, disease development is rapid; fruit rot and/or dieback of the top growth above stem cankers may occur. Early infections on fruits are seen as a light colored or silvery ring “ghost spot” with a brownish spot in the center. Under humid conditions, the causal fungus (*Botrytis cinera*) produces abundant masses of felty grey spores on infected plant parts.

Control: Follow good cultural and sanitation practices. If added protection is required, apply sprays of the following fungicides:

– Dyrene 50% WP at 200 g - 1 day, or

– Belate 50% WP at 100 g in a tank mix with 200 g of either Eithane M-45 or Manzate 200 - 1 day, or

– Exotherm Termil smoke generators, or

– Botran 75% WP at 175 g - 1 day.

Note: Spray only stems of plants up to a height of 60 cm (24 inches). Temporary injury may occur on the foliage of young tomatoes.

– Rovral 50% wp at 100g - 2 days.

Leaf Mold

The symptoms of this disease are yellowish-green indefinite areas on the upper surface of leaves accompanied by brown to purplish, velvety growth of the causal fungus (*Cladosporium fulvum*) on the undersides. Fruit, stems and blossoms may also be affected when the atmosphere is humid.

Control: Follow the same cultural and sanitation practices discussed for early blight of tomatoes. If additional protection is required, apply a spray of Benlate 50% WP at 100 g in a tank mix with 200 g of either Dithane M-45 or Manzate 200 - 1 day.

Magnesium Deficiency

This is a non-infectious disease caused by inadequate availability of magnesium. Characteristic symptoms are a pale green or yellow coloration between the veins of older leaves.

High potassium levels in the soil may induce magnesium deficiency.

Control: Rotate plantings to new beds. Apply magnesium sulphate (Epsom salts) to soil at 1 kg/100 m^2 or to the leaves once as a spray at 100 g/100 L. In greenhouses where the problem has occurred on previous crops, magnesium sprays should be applied even before the symptoms occur.

Sclerotinia Stem Rot

The cause and symptoms of this disease are similar to those discussed for Sclerotinia stem rot of cucumbers.

Control: Follow cultural and sanitation practices outlined in the Sanitation Section. If chemical control is required, apply Benlate 50% WP at 100 g in a tank mix with 200 g of either Dithane M-45 or Manzate 200 - 1 day.

Virus Diseases

The three most damaging virus diseases of tomatoes in Alberta are common mosaic (Tomato Mosaic Virus = TMV), streak (Potato Virus X = PVX and TMV) and shoestring (Cucumber Mosaic Virus = CMV). Common mosaic is widespread and well known to most growers. Its main symptom is light to dark green mottling on the leaves often accompanied by wilting of young leaves on sunny days when plants first become infected. Affected leaflets may be distorted, puckered or undersized. Plants infected with severe strains of TMV are often pale-colored, spindly and stunted. Occasionally, brown markings and blotches occur on the green and ripe fruits. Streak may produce similar symptoms to common mosaic; however, it is usually characterized by a sudden wilting and dying of the tips of the youngest shoots and a virtual stoppage of growth. Dark brown to black streaks form on the stems and petioles. Streak-infected plants usually die prematurely. Shoestring produces very narrow, spindly leaves and mottling symptoms in the leaves similar to common mosaic. Sometimes, leaf blades are so pronounced that a "shoestring" leaf is formed. Plants affected by shoestring generally become stunted and nonproductive.

Control: TMV:

– Spray seed flats with skim milk the evening before pricking out.

– Do not smoke or handle any form of tobacco in tomato greenhouses.

– To destroy surface-borne TMV on tomato seed, soak seed for 15 minutes in trisodium phosphate (100 g/L). Rinse thoroughly in clean water and dry.

Control: Streak:

– Follow the control measures given for common mosiac.

– Avoid handling potatoes before working in tomatoes.

Control: CMV:

– Control weeds and aphids that may harbor and spread the virus.

As a general practice for all three viruses, rogue out affected seedlings and plants if disease appears early. After handling diseased plants, field tomatoes, potatoes, bedding plants, and after smoking or handling tobacco in any form, wash hands with soap and water because viruses may be carried to greenhouse plants from such sources.

Wilt

Two fungi (*Verticillium spp*. and F*usarium oxysporum* f. sp. *Lycopersici*) can cause wilt disease of greenhouse tomatoes. Both organisms are soil-borne and attack through the roots. With Verticillium wilt, the first foliar symptom usually observed is the wilting of one or more leaflets on a single leaf. The oldest leaves usually show symptoms first and then wilt develops progressively in the younger leaves. Frequently, the first symptoms appear on leaflets only on one side of the leaf. V-shaped yellowed areas extending in from the leaf margins are occasionally seen. A brown discoloration of the water-conducting tissues of the stem may develop in plants with well-established infection. Fusarium wilt causes a progressive wilting and death of tomatoes and usually affects plants more uniformly and drastically than Verticillium wilt. The vascular and woody tissues of the stems of affected plants often show a brown discoloration.

Control: Steam or chemically fumigated soil between crops or change to a soilless system of growing. Grow wilt resistant varieties, if available.

Nutrient Disorders

Mobile elements (first symptom on lower leaves)

Nitrogen

Spindly plant

– Lower leaves - yellowish green

– Severe cases - entire plant pale green

– Major veins - purple color

– Small fruit

Remedies:

1. Use a foliar spray of 0.25-0.5 per cent solution or urea.

2. Add calcium nitrate or potassium nitrate to the feeding program.

Phosphorus

Shoot growth restricted

Thin stem

Severe cases - leaves small, stiff, curved downward

Leaf upper sides - bluish green

Leaf undersides - including veins - purple

Older leaves - yellow with scattered purple dry spots - premature leaf drop

Remedies:

1. Add monopotassium phosphate to nutrient solution.

2. Add soluble phosphorus fertilizers to the growing medium.

Potassium

Older leaves - leaflets scorched, curled margins, interveinal chlorosis, small dry spotss

Middle leaves - interveinal chlorosis with small dead spots, plant growth restricted, leaves remain small

Later Stages - chlorosis and necrosis spreads over large area of leaves, also up plant, leaflets die back

Fruit - Blotchy, uneven ripening, greenish areas

Remedies:

1. Foliar spray of 2% potassium sulphate.

2. Add potassium sulphate or if no sodium chloride present in water, can add potassium chloride to the feeding program.

Magnesium

Older leaves - marginal chlorosis progressing inwards as interveinal chlorosis necrotic spots in chlorotic areas

Small veins - not green

Severe starvation - older leaves die, whole plant turns yellow, fruit production reduced.

Remedies:

1. Foliar spray with 2% magnesium sulphate.

2. Add magnesium sulphate to nutrient solution or feeding mixture.

Zinc

Older leaves and terminal leaves - smaller than normal. Little chlorosis, but irregular shrivelled brown spots develop, especially on petioles (small petioles of leaflets) and on and between veins of leaflets.

Petioles - curl downward, complete leaves coil up.

Severe starvation - rapid necrosis, entire foliage withers.

Remedies:

1. Foliar spray with 0.1-0.2 per cent solution of zinc sulphate.

2. Add zinc sulphate to nutrient solution or feeding mixture.

Immobile elements (first symptoms on younger leaves).

Calcium

Upper leaves - marginal yellowing, undersides turn purple-brown colorespecially on margins, leaflets remain tiny, deformed, margins curl up.

Progression to later stages - leaf tips and margins wither, curled petioles, die back

Growing point dies

Older leaves - chlorosis and necrotic spots form in later stages of deficiency

Fruit - blossom-end rot (leathery-like decay at blossom ends of fruit).

Remedies:
1. In acute cases, foliar spray with 0.75-1.0% calcium nitrate solution. Can also use 0.4% calcium chloride.

2. Add calcium nitrate to nutrient solution, or calcium chloride if you do not want to increase the nitrogen level. Be sure there is little, if any, sodium chloride in the nutrient solution if calcium chloride is used.

Sulphur

Upper leaves - stiff, curl downward, eventually large irregular necrotic spots appear, leaves become yellow.

Stem, veins, petioles - purple

Older leaves, leaflets - necrosis at tips and margins, small purple spots between veins.

Remedies:
1. Add any sulphates to the nutrient solution. Potassium sulphate (0-0-50) would be safest since the plants require high levels of potassium.

Note: Sulfate deficiency rarely occurs since sufficient amounts are added by use of potassium, magnesium and other sulphate salts in the normal nutrient formulation.

Iron

Terminal leaves - chlorosis starts at margins and spreads through entire leaf, initially smallest veins remain green, giving reticulate pattern of green veins of yellow leaf tissues; leaf eventually turns completely pale yellow, no necrosis.

Progression - symptoms start from terminal leaves and work down to older leaves.

Growth - stunted, spindly, leaves smaller than normal

Flowers - abortion

Remedies:
1. Foliar spray with 0.02-0.05% solution of iron chelate (Fe-EDTA) every week for 3-4 weeks.

2. Add iron chelate to nutrient solution.

Boron

Growing Point - shoot growth restricted, leads to withering and dying off growing point.

Upper leaves - interveinal chlorosis, mottling of leaflets, remain small, curl inward, deformed, smallest leaflets turn brown and die

Middle leaves - yellow-orange tints, veins yellow or purple

Older leaves - yellowish-green

Lateral shoots - growing points die

Petioles - very brittle, break off easily, clogged vascular tissue

Remedies:
1. Apply a foliar spray as soon as detected of 0.1% solution of borax.

2. Add borax to nutrient solution

Copper

Middle and younger leaves - margins curl into a tube toward the midribs, not chlorosis or necrosis, bluish-green color, terminal leaves small, stiff and folded up.

Petioles - Bend downward, directing opposite tubular leaflets toward each other.

Stem - Growth stunted

Progression - Later stages get necrotic spots adjacent to and on midribs and large veins

Remedies:
1. Foliar spray with 0.1% solution of copper sulphate to which 0.5% hydrated lime has been added

2. Add copper sulphate to nutrient solution

Manganese

Middle and older leaves - turn pale, later younger leaves also, characteristic checkered pattern of green veins and yellowish interveinal areas, later stages get small necrotic spots in pale areas, chlorosis less severe than in iron.

Remedies:
1. Foliar spray using 0.1% solution of manganese sulphate deficiency, also chlorosis is not confined to younger leaves as is the case with iron.

2. Add manganese sulphate to nutrient solution or feeding mixture

Molybdenum

All leaves - leaflets show a pale green to yellowish interveinal mottling, margins curl upward to form

a spout, smallest veins do not remain green, necrosis starts in the yellow areas, at the margins of the top leaflets and finally includes entire composite leaves which shrivel.

Progression - from the older to the younger leaves, but the cotyledons stay green for a long time.

Remedies:
Use sodium or ammonium molybdate as foliar spray 0.07-0.1%.

Insect Control

Aphids

Apply one of the following according to label directions:

– Greenhouse Dibrom 10 ml/100 m^3 on heating pipes (1 day).

– Parathion smokes (1 day).

– Nicotine smokes OR pressure fumigators (1 day).Corn Earworm, Cabbage Loopers and Tomato Hornworm

Where infestations are severe, spray with Dipel or Turcide HPC using label rates (1 day). Hand-picking usually gives adequate control of hornworms.

Cutworms

Apply a poison bran bait at 1.25 kg/100 m^2. The bait consists of Sevin 50% WP 1 kg stirred into 11 L water, mixed with 12 kg bran.

Greenhouse Whitefly

For chemical control, use one of the following:

– Ambush 50 EC 20 ml (1 day)

Greenhouse Dibrom 10 ml/100 m^3 on heating pipes (1 day).

– Thiodan 4 EP 125 ml/100 L (2 days).

Note: Many strains of whitefly are resistant to Thiodan; others may develop resistance after repeated applications.

– Parathion smokes (1 day). Generally effective only against light infestations and in small greenhouse areas.

The above materials mainly control adults. Repeat applications at 5-day intervals to prevent egg-laying by newly emerged adults.

Leaf Miner

Occasionally a problem in the fall crop. Control measures must begin when adults first appear.

– Ambush 50 EC, used as for greenhouse whitefly will also control leaf miners, or apply

Root-Knot Nematode

See Sanitation Section

Thrips

Seldom troublesome on tomatoes. If required, use one of the chemicals listed for aphids, but exclude Nicotine smokes.

Two-Spotted Spider Mite

Rarely a pest of tomato. If required, use one of the following:

– Vendex 50W 50 g (5 days).

– Kelthane 18.5 EC, 125 ml (2 day).

– Tedion smokes (1 day).

– Greenhouse Dibrom 10 ml/100 m^3 on heating pipes (1 day).

Slugs

Apply a commercial slug bait containing metaldehyde.

Note: Metaldehyde is poisonous to pets. Keep dogs and cats out of treated areas.

Sowbugs

Spray surface of soil with 50 per cent Sevin WP at 95 g/50 L of water on 25% malathion WP at 190 g/50 L of water.

PEPPER PRODUCTION

Currently the major greenhouse crops grown in Alberta in order of importance are cucumbers and tomatoes. Limited production of pepper and lettuce does take place. There is an interest in growing peppers because of success in Ontario and British Columbia.

The annual yields reported from Ontario ranged from 10 to 15 kg/m^2, with a price range of $4.00 to 10.00/kg. This coupled with an estimated 25 per cent reduction in labor requirements, makes peppers an interesting alternative for many growers. The major problem is the very long period of time (up to 150 days) from first seeding to harvest.

Varieties

Most sweet bell peppers are green maturing to either red or yellow. For green to red use:

Delphin - 158 g fruit weight
Plutona - 146 g fruit weight
Tango

For green to yellow use:

Luteus
Goldstar

Germination

Soak seeds in a 10 per cent solution of trisodium phosphate (T.S.P.) for one hour before seeding to control tobacco mosaic virus. Maintain the media temperature at 26°C until pricking out (transplanting). The air temperature should be 24°C.

Germinate the seeds in a previously moistened soilless mix. Cover the seeds with 5 mm of clean sand to help remove the seed coat from the cotyledons when they emerge. Provide good light to avoid stretching.

The seedlings are ready for pricking out once the first true leaves appear.

Temperatures after pricking out:

Media - 21°C
Day - 23-24°C
Night - 19-20°C

Plant Raising

Seedlings can be planted into 10-14 cm azalea pots. The potting mix as recommended on page is satisfactory. Growers may wish to feed fertilizer solution rather than adding mag-amp to the mix. Pots should be arranged so leaves do not overlap. If rockwool is used, a 7.5 cm or 10 cm block is recommended. These should be thoroughly wetted with fertilizer solution prior to transplanting. Make the best use of available light. Supplemental illumination may be beneficial at this stage.

Feed plants at each watering with a complete nutrient food. Carbon dioxide enrichment to 900 ppm is recommended for better quality plants.

Plant Density

For earlier crops, planted out before May, a density of 3 plants per square metre (two shoots per plant) is recommended. After May, use a spacing of 2 plants per square metre and allow 4 shoots per plant.

Crop Timing

During the winter months it takes longer to raise a plant to the final planting out stage. Use the following table to plan seeding dates.

Date of Planting Out	Age of Plant Needed (from Seeding)	Date to Allow First Fruits to Set
Before Dec. 5	58-63 days	6 weeks after planting
Dec. 5 - Dec. 20	60-65 days	Jan. 25
Dec. 20 - Jan. 10	75-82 days*	Feb. 1
Jan. 10 - April 15	80-90 days*	3-4 weeks after planting
After April 15	50 days	3-4 weeks after planting

* Supplemental illumination may reduce the rearing time by as much as 3 weeks at this time of year.

Training and Pruning

At about 4 weeks after planting out, select 2 to 4 of the tallest shoots. Wrap these shoots around strings fastened to wires about 2.5 metres from the ground (similar to tomatoes). Trim off any other side shoots at about 3 leaves. The shoot tips will require twisting around the strings every 2 to 4 weeks. If plants tend to overset, remove enough small fruit to avoid crowding. Remove any misshapen fruit as early as possible.

Climate

Maintain a relative humidity of about 75 per cent. Low humidities will reduce growth and stimulate flower bud formation and branching. High humidity can slow down the rate of transpiration and encourage diseases like botrytis. To stimulate the first fruit to set, maintain 15 to 17°C night temperatures and 20 to 23°C days. For mature plants with a full fruit load, increase the night temperature to 17 to 18°C.

Ventilation temperatures should be 5°C higher than the heating set point, except for first fruit setting, when a difference of only 1°C should be used.

Feeding

Use the cucumber fertilizer formula on pages 24-27.

Upon planting out, place drippers on the bags at the edge of the root ball. Allow three drippers per bag.

Time fertilizer applications at regular intervals during the day such as hourly or hourly if using a time clock system. Allow 10-20% leaching to ensure no soluble salt accumulation. Start with 800 to 1000 ml per day and adjust feeding volumes upwards as sunlight and size of plants increase. Rates given to mature plants will be 4 to 5 litres per bag per day. Keep the sawdust moist but not saturated. Ensure that the feeding solution temperature is 20°C (minimum) when applied.

Contact the Greenhouse Specialist for specific input into fertilizer programs on NFT and Rockwool.

Harvesting

Harvest peppers with a sharp knife in the morning when the fruit are still cool. Warm fruit will become soft sooner. The use of a sharp knife will leave a smooth surface on the stem, which adds to the appearance and reduces the incidence of botrytis in the crop.

Pepper fruit will continue to color after harvest, so some green on the fruit at picking is acceptable. The fruit must be fully red or yellow at the time of sale. Coloring will be faster at higher temperatures and therefore more green is allowed at harvest during the summer.

Harvesting crates should be lined with foam. Peppers should be placed in the containers, not tossed from a distance, to avoid damage to the fruit. The peppers should not be exposed to full sunshine and should be shipped to the packing/shipping area as quickly as possible.

High plant vigor can be controlled by leaving some fruit on the plant.

Fruit Disorders

Buttons

Buttons are severely misshapened peppers which contain few or no seeds. They are usually short and small. Buttons can often be detected during bloom - generally the large, coarse flowers that bloom over a long period will produce buttons. Low daytime temperatures, low relative humidity, and/or overly vigorous plants can all result in buttons. If the fruits on the first set are all picked at one time this may result in vigorous growth and later development of buttons.

Russeting

Russeting is the occurrence of small cracks in the outer fruit wall. The cause of russeting is not yet well understood. A number of factors apparently contribute to this disorder.

The tail end of a heavy set is likely to be russeted. Once the first fruits of a flush are harvested, the remaining fruits get an extra "push". An already tough skin will not be able to absorb the extra swelling and will crack.

Other factors which may contribute to russesting are low EC of the soil moisture, condensation, RH and a large difference between

day and night temperature. Periods of cool, dark weather are known to cause an increase in russeting.

Pitting

Pitting occurs primarily on ripe peppers and is caused by small concentrations of dead cells in the fruit wall. Pitting occurs primarily when weather conditions favor strong vegetative development. Affected fruits have a higher calcium content.

Internal Growth, Wings and Tails

Internal growth is abnormal development of honey glands on the inside of the fruit. It can occur during the first flush. In serious cases, it may even cause the fruit to burst.

Wings are also honey glands, developing from the calyx.

Tails develop at the flower end of the fruit from parts of the style that did not die. Tails break off easily during harvest and handling, leaving an wound where rotting can start. A long flowering period, caused by low temperatures, is thought to be one of the contributing factors.

Shoulder Cracks

Shoulder cracks are fresh, open, wet wounds caused by irregular transpiration and water uptake just before harvest. Reduced transpiration due to poor weather, too much water, or a sudden reduction in EC may cause shoulder cracks. Yellow peppers are particularly sensitive.

Blossom End Rot (BER)

BER can be a serious problem. BER is caused by too high temperatures, too high salt concentrations, low calcium, and/or low RH.

Grading and Storage

	Distance across the shoulder	
Small	55-65 mm	2.2-2.5 inches
Medium	65-75 mm	2.5-3.0 inches
Large	75-85 mm	3.0-3.3 inches
Extra Large	over 85 mm	over 3.3 inches

Peppers should be stored at 7-8°C. Temperatures below 5°C will cause damage. The storage temperature will affect the rate of coloring:

	No. of days to reach 100% color at indication temperature									
	Yellow Peppers					Red Peppers				
Harvested	°C					°C				
at	8	12	15	20	24	8	12	15	20	24
50% green	24	16	11	8	10	17	10	9	9	11
30% green	23	13	9	7	7	13	9	8	8	10
10% green	16	10	6	6	4	10	8	7	7	7

Disease and Insect Control

Contact your local greenhouse specialist at either of the following locations for specific recommendations:

Alberta Special Crops &
Horticulture Research Center
Bag 200
Brooks, Alberta T0J 0J0
or

Alberta Tree Nursery &
Horticulture Centre
R.R. #6
Edmonton, Alberta T5B 4K3

PESTICIDE SAFETY

Know Your Pesticides

Read the label - read it all, even the small print.

Know the relative toxicity and hazards of the pesticide.

Use pesticides only when they are actually needed. Use only the pesticide that is recommended for the problem.

Code for the Safe Handling and Use of Pesticide

1. Always read the label before opening the container.

2. Use at recommended rates. Apply as directed.

3. Wear clean protective clothing as outlined on the label.

4. Do not inhale fumes, spray or dusts. Avoid skin contact. Wash immediately after accidental contact.

5. If pesticides are spilled on clothes, change immediately.

6. Do not eat, smoke or drink when mixing or applying or until after wash-up.

7. Follow "days to harvest" on label and in this production guide.

8. Cover food and water containers when treating around livestock or pet areas. Do not contaminate water.

9. If any illness or abnormal condition occurs during or shortly after pesticide use, call a doctor immediately.

10. Wash equipment thoroughly after each pesticide application.

11. Shower or bath thoroughly after working with pesticides.

12. Use separate equipment for applying hormone type herbicides in order to avoid accidental injury to susceptible plants.

13. Always store pesticides in original containers and keep storage locked.

14. Keep ALL pesticides out of reach of children and animals.

15. Take precautions to reduce hazardous pesticide drift.

Protective Clothing

Wear coveralls, respirator, boots, gloves and a wide brim hat when using very toxic pesticides. Do not tuck pant cuffs inside your boots. Use waterproof clothing if there is a danger of getting wet from spray.

For less toxic pesticides, adequate clothing should be worn to prevent skin contact. Wear rubber or neoprene gloves and goggles when mixing any pesticides.

Clean protective clothing after use.

Respirators

Respirators must be worn when specified on the label. Make certain that your respirator fits and is rated to give protection for the chemical you intend to use.

Respirator cartridges remove toxic chemicals from the air. Dust filters simply remove dust. Both must be replaced regularly for the respirator to be effective. Use manufacturer's directions or maintain your respirator as follows:

1. Change felt dust filters after 4 hours of use or more often if breathing becomes difficult.

2. Change cartridges after 8 hours of use, or sooner if any odor of pesticide is noticed.

3. Wash the facepiece of a respirator with warm soap and water after using, rinse thoroughly with clean water and dry well with a clean cloth.

4. Keep your cleaned respirator in a clean, dry place enclosed in a sealed plastic bag.

Indoor use of Fumigants, Smoke Generators and Foggers

When applying extremely toxic or very toxic pesticides indoors, a full face gas mask with correct canister should be used. Keep a fresh canister on hand as they lose their effectiveness after a certain time.

For methyl bromide, a self-contained breathing apparatus which supplies clean air is recommended for indoor work. However, a gas

mask with a special canister can be used when applying the fumigant if you leave the area immediately.

Wear a full face mask when lighting a smoke generator and when aerating the house. Light the bomb farthest from the door and work toward the door. If smoke bombs are placed in more than one path, more than one person should light them.

When using fogging machines, wear complete protective clothing including hat, jacket, pants or coveralls, rubber gloves and an airtight, full-face mask.

Disposal of Unwanted Pesticides

Calculate accurately the amount of pesticide needed so that a minimal amount is left over.

Drain small amounts of leftover spray into a hole in an isolated area and cover the hole with soil. Pesticides must not be dumped near any waterway.

For information on disposal of pesticides products, contact the regional office in the
Pesticide Chemical Branch,
Pollution Control Division
Alberta Environment,
5th Floor, Oxbridge Place, 9820 - 106 Street,
Edmonton, Alberta T5K 2J6.

Disposal of Containers

Destroy or dispose of empty triple-rinsed containers immediately; do not leave empty containers scattered around.

Dispose of empty pesticide containers by burial in a sanitary land fill. If there is no public landfill in the area, flatten containers and bury them at least 45 cm deep where there is no danger of water contamination.

Some pesticide labels caution against burning of packages. Fumes may be toxic or damaging to plants. If burning is safe, bury the ashes.

Glass jars should be broken in the burial pit and metal or plastic containers crushed or punched with holes to render them useless.

Storage

1. Keep pesticides out of reach of children and pets. Legally all pesticides must be stored in a ventilate, locked shed with a warning sign on the door. Store away from food, feeds, fertilizers and seeds.

2. Store volatile herbicides separately from other pesticides, fertilizers and seeds.

3. Always store pesticides in their original containers. Keep the containers tightly closed and dry. Avoid freezing of liquid formulations.

4. When not in use return pesticides to storage.

5. Dispose of:

   a) pesticides no longer required

   b) containers which are unmarked, corroded or damaged.

For disposal instructions see above.

Records

Keep good records of all pesticide use.

The danger of applying pesticides and fertilizer through the irrigation system

Pesticide application through the irrigation system is not recommended because such an application presents a real danger to the water supply.

After Applying Pesticides

Clean the equipment thoroughly.

Clean and store your clothing and protective equipment.

Wash yourself thoroughly.

Observe the required waiting period before harvest.

The danger of filling the sprayer tank for stand pipes, from domestic water taps, lakes or streams

If the end of the filler hose is submerged in the spray liquid during filling, there is a danger of contaminating the water supply by backflow. A 15 cm air gap must be maintained between the end of the filler hose and the liquid in the tank. Use an antifoaming agent or 15 ml of cooking oil to prevent foaming.

If filling spray tanks from a lake or stream, equipment must have an anti-siphon check valve.

Symptoms of Pesticide Poisoning

Read the label for poisoning symptoms. The symptoms of pesticide poisoning vary from person to person and are often difficult to recognize. If any illness or abnormal condition occurs during or after exposure to pesticides, contact a doctor immediately. Provide him with label information.

Call your doctor or Poison Control Centre immediately if there has been a suspected poisoning.

The label has detailed first aid information.

Give the information to the doctor.

For your convenience, space has been made available on the front cover of you telephone directory for the telephone numbers of your Poison Control Centre and doctor.

Warning: Do not induce vomiting if a corrosive (acid or alkali) or petroleum product is accidentally swallowed.

Poison Control Centres

All hospitals in Alberta are poison control centres. They provide first aid information and treatment of poisoning for toxic chemicals.

Know the telephone number of your nearest hospital.

Re-entry into Treated Areas

It is your responsibility to warn your farm workers of areas recently treated with pesticides have. Pesticide poisoning may occur where workers enter treated areas too soon after pesticides have been applied. Such poisoning may result from inhalation of pesticide vapors but more often from handling treated plants.

For some pesticides, e.g., parathion and Guthion, the label carries a warning regarding working in treated crops. Follow these directions. Where no label warnings are provided, it is advisable to wait at least 24 hours following spray application of any material rated as very toxic (dermal or oral) as listed in the 'Relative Toxicity of Pesticides' table in this publication, before re-entry.

Longer periods are advised where wettable powder formulations of these materials have been used and when there will be substantial contact with the sprayed foliage. Although there is a lack of specific information on how long this period should be, a minimum of 48 hours is suggested.

Relative Toxicity of Pesticides

The toxicity data are based on tests with rats and rabbits and are considered relevant to all mammals including humans. The principal source of information for the table is Acute Toxicity Data for Pesticides (1970), R. Ben Dyke, D.M. Sanderson and Diana N. Noakes. The following categories have been used: Dermal - LD50, 0-200, very toxic; 200-1,000 toxic; 1,000 up, slightly toxic. Oral - LD50, 0-50, very toxic, 50-500, toxic, 500 up, slightly toxic.

Very Toxic

ORAL (by mouth)	DERMAL (skin absorption)
chloropicrin	chloropicrin
Cyanogas	Cyanogas
Gramozone (paraquat)	methyl bromide
methyl bromide	parathion
Mouse Bait 2 – (zinc phosphide)	
parathion	
Ramik Brown (diphacinone)	
Thiodan – (endosulfan)	
zinc phosphide	
calciferol	
brodifacoum	
bromadiolone	

Although the toxicity rating of Gramoxone (paraquat) has not been clearly established as "very toxic" there is no doubt that swallowing it could be fatal. There is no specific antidote for Gramoxone (paraquat). Use extreme caution to avoid accidental swallowing of this herbicide.

Toxic

ORAL (by mouth)	DERMAL (skin absorption)
diazinon	formaldehyde
Dibrom (naled)	Thiodan (endosulfan)
fixed copper	
formaldehyde	
Plictran (cyhexatin)	
Sevin (carbaryl)	

Slightly Toxic

ORAL (by mouth)

Ambush (permethrin)
Benlate (benomyl)
Botran (dichloran)
Bravo (chlorothanlonil)
captan
Daconil (chlorothalonil)
Dyrene (anilazine)
Exotherm Termil Ethrel (ethephon) (chlorothalonil)
Kelthane (dicofol)
mancozeb
maneb
metaldehyde
Tedion (tetradifon)
Termil (chlorothalonil)
thiram
Vapam (metam)
Vendex
Roundup (glyphosate)

DERMAL (skin absorption)

Ambush (permethrin)
Benlate (benomyl)
Bravo (chlorothanlonil)
captan
Daconil (chlorothalonil)
diazinon
Dibrom (naled)
Exotherm Termil (chlorothanlonil)
Filed copper
Kelthane (dicofol)
mancozeb
maneb
Metaldehyde
Plictran (cyhexatin)
Roundup (glyphosate)
Sevin (carbaryl)
Tedion (tetradifon)
Termil (chlorothanlonil)
thiram
Vapam (metam)
Vendex (fenbutatin oxide)

PESTICIDES

Trade names are capitalized. Common names are not capitalized.

Fungicides

Arasan	thiram
Benlate	benomyl
Benomyl	Benlate
Botran	dechloran
Bravo	chlorothalonil
captan	Captan, Orthocide
chlorothalonil	Daconil, Exotherm, Termil
Copper oxychloride	fixed copper
Daconil	chlorothalonil
Exotherm Termil	chlorothalonil
fixed copper	Neutro-Cop, Tri-Cop
Orthocide	captan
Termil	chlorothalonil
thiram	Thiram, Arasan, Thylate
Thylate	thiram
Tri-Cop	fixed copper

Insecticides

Basudin	diazinon
carbaryl	Sevin
diazinon	Basudin
Dibrom	naled
naled	Dibrom
parathion	Parathion
Sevin	carbaryl
Ambush	permethrin

Fumigants

chloropicrin	Chloropicrin
Cyanogas	Cyanogas
Dowfume MC-2	methyl bromide
formaldehyde	formalin
formalin	formaldehyde
metam	Vapam
methyl bromide	Dowfum MC-2
Vapam	metam

Molluscicide

metaldehyde	Slug Bait
Slug Bait	metaldehyde

Miticides

dicofol	Kelthane
Kelthane	dicofol
Tedion	tetradifon
tetradifon	Tedion
vendex	fenbutatin oxide

Herbicides

glyphosate	Roundup
Gramoxone	paraquat
paraquat	Gramoxone
Roundup	glyphosate

Rodenticides

bradifacoum	Ratak, Talon
bromadiolone	Bromone, Maki
Bromone	bromadiolone
caciferol	Sorexa
Maki	bromadiolone
Mouse Bait 2	zinc phosphide
Ratak	brodifacoum
Sorexa	calciferol
Talon	brodifacoum
zinc phosphide	Mouse Bait 2

VEGETABLE RESEARCH AND EXTENSION STAFF

SPECIALIZATION	NAME	POSITION	ADDRESS
Greenhouse Production	Judy Butt	Greenhouse Specialist	Alberta Special Crops & Horticulture Research Center, Bag 200 Brooks, Alberta T0J 0J0 362-3391
	M. Mohyuddin	Greenhouse Specialist	Alberta Tree Nursery & Horticulture Centre R.R. #6 Edmonton, Alberta T5B 4K3 472-6043
General Vegetable Production	Paul Ragan	Research Horticulturist Vegetable Crops	Alberta Special Crops & Horticulture Research Center, Bag 200 Brooks, Alberta T0J 0J0 362-3351
	B. Choban	Vegetable Crop Extension Specialist	Alberta Tree Nursery & Horticulture Centre R.R. #6 Edmonton, Alberta T5B 4K3 472-6043
Disease Control	Ron Howard	Plant Pathologist	Alberta Special Crops & Horticulture Research Center, Bag 200 Brooks, Alberta T0J 0J0 362-3351
	Jim Letal	Horticulture Crop Development Specialist	Alberta Tree Nursery & Horticulture Centre R.R. # 6 Edmonton, Alberta T5B 4K3 472-6043
	P.D. Kharbanda	Plant Pathologist	Alberta Environmental Research Centre, Bag 4000 Vegreville, Alberta T0B 4L0, 632-6767
	David Sippell	Plant Pathologist	Regional Crops Laboratory Box 7777 Fairview, Alberta T0H 1L0 835-2291
Insect Control	M. Steiner	Entomologist	Alberta Environmental Centre Bag 4000 Vegreville, Alberta T0B 4L0, 632-6767
Weed Control	Rudy Esau	Weed Control Specialist	Alberta Special Crops & Horticulture Center, Bag 200 Brooks, Alberta T0J 0J0 362-3391

Soil Fertility	R.C. McKenzie	Soil & Water Specialist	Alberta Special Crops & Horticulture Research Center, Bag 200 Brooks, Alberta T0J 0J0 362-3391
	D. Penney	Soil Fertility Specialist	J.G. O'Donoghue Building 7000 - 113 Street Edmonton, Alberta T6H 5T6 427-5373

GREENHOUSE SOIL ANALYSES LABORATORIES

Seed Companies

1. Bruinsma Selectie Bedrijven
   Vegetables and Flower Seeds
   822, 7 Street, West
   P.O. Box 1463
   High River, Alberta T0L 1B0
   (403) 652-4768

2. De Ruiter Seeds Inc.
   P.O. Box 20228
   Columbus, Ohio 43220
   United States
   (614) 459-1498

3. Professional Gardener Ltd.
   915 - 23 Avenue, S.E.
   Calgary, Alberta T2G 1P1
   (403) 263-4200

4. Stokes Seeds Ltd.
   39 James Street
   Box 10
   St. Catharine, Ontario L2R 6R6

5. Petoseed Co. Inc.
   P.O. Box 4206
   Staticoy, California 92003
   United States

Soil, Water

1. Alberta Agriculture
   Soil and Animal Nutrition Laboratory
   O.S. Longman Building
   6909 - 116 Street
   Edmonton, Alberta T6H 4P2
   (403) 427-6361
   (403) 436-9150

Soil, Tissue, Water

2. Professional Gardener Ltd.
   915 - 23 Avenue, S.E.
   Calgary, Alberta T2G 1P1
   (403) 263-4200

3. Norwest Soils Research Ltd.
   9938-67 Avenue
   Edmonton, Alberta T6E 0P5
   (403) 438-5522

METRIC UNITS

Symbols

Length

mm millimetre
cm centimetre
m metre
km kilometre

Pressure

kPa kilopascal

Area

cm^2 square centimetre
m^2 square metre
ha hectare
km^2 square kilometre

Weight

g gram
kg kilogram
t tonne

Volume

ml millilitre
L litre
hL hectolitre
m^3 cubic metre

Temperature

°C degrees Celsius

Prefixes

mega	million	1 000 000	deci	tenth	0.1
kilo	thousand	1 000	centi	hundredth	0.01
hecto	hundred	100	milli	thousandth	0.001
deca	ten	10	micro	millionth	0.0001

Measures

Length

10 mm	1 cm
100 cm	1 m
1 000 m	1 km

Volume

1 000 ml	1 L
100 L	1 hL
1 000 L	1 m^3

Interrelationship

Water at 4°C		Volume	Weight
1 000 cm^3	1 000 cc	1 L	1 kg
1 cm^3	1 cc	1 ml	1 g

Weight

1 000 g	1 kg
1 000 kg	1 t

Area

10 000 cm^2	1 m^2	(100 cm x 100 cm)
10 000 m^2	1 ha	(100 m x 100 m)
100 ha	1 km^2	(1000 m x 1000 m)

CONVERSION FACTORS

Imperial Units	Conversion Factor	Metric Units
LENGTH		
inches	2.5	centimetres
feet	30	centimetres
feet	0.3	metres
yards	0.9	metres
miles	1.6	kilometres
AREA		
square inches	6.5	square centimetres
square feet	0.09	square metres
acres	0.40	hectares
VOLUME		
cubic inches	16	cubic centimetres
cubic feet	0.03	cubic metres
cubic yards	0.8	cubic metres
fluid ounces	28	millilitres
pints	0.57	litres
quarts	1.1	litres
gallons (Imperial)	4.5	litres
gallons (U.S.)	3.75	litres
bushels	0.36	hectolitres
WEIGHT		
ounces	28	grams
pounds	0.45	kilograms
short tons (2,000 lb)	0.9	tonnes
TEMPERATURE		
degrees Fahrenheit (F-32)	0.56	degrees Celsius
POWER		
horsepower	750	watts
	0.75	kilowatts

Imperial Units	Conversion Factor	Metric Units
oz/acre	70	g/ha
lb/acre	1.12	kg/ha
bu/acre	0.9	hL/ha
tons/acre	2.24	t/ha
fl oz/acre	70	ml/ha
pt/acre	1.4	L/ha
qt/acre	2.8	L/ha
gal/acre	11.2	L/ha
gal/acre (U.S.)	9.35	L/ha
plants/acre	2.47	plants/ha
oz/gal	6.2	ml/L
lb/gal	0.1	kg/L
oz/ft^2	305	g/m^2
lb/ft^2	4.9	kg/m^2
oz/ft row	93	g/m row
lb/ft row	1.5	kg/m row
ft/sec	0.3	m/s

mph	1.6	km/h
psi	6.9	kPa
PRESSURE		
psi (lb/in.^{2})	6.89	kilopascals (kPa)
inches of water	0.25	kilopascals (kPa)
ENERGY		
British thermal unit (Btu)	1.06	kilojoules (kJ)
Btu/hr	0.293	watts (W)
Btu/hr/sq ft	3.15	watts per square metre (W/m^2)
kilowatt hours	3.60	megajoules (MJ)

Parts Per Million

1 percent = 10,000 parts per million
Imperial: 1 fl oz/gallon = 6250 ppm
Metric: 1 mg/litre (water) = 1 ppm
1 g/litre (water) = 1000 ppm
1 ml/litre = 1000 ppm

$$\text{PPM} = \frac{\text{grams of fertilizer product x grade of fertilizer x 10}}{\text{litres of water in solution}}$$

Solubility of Fertilizers in Cold and Hot Water

Fertilizer	Solubility g per 100 ml Water	
	Cold	Hot
Ammonium nitrate	118.3(0)	871.0(100)
Ammonium sulphate	70.6(0)	103.8(100)
Calcium nitrate	102.5(0)	376.0(100)
Urea	78.0	
Monoammonium phosphate	22.7(0)	173.2(100)
Diammonium phosphate	57.5(0)	106.0(70)
Potassium carbonate	112.0(20)	156.0(100)
Potassium chloride	34.7(20)	56.7(100)
Potassium nitrate	13.3 (0)	247.0(100)
Potassium sulphate	12.0(25)	24.0(100)
Potassium orthophosphate	90.0	(20)
Monopatassium phosphate	167.0	(20)
Magnesium sulphate	26.0(0)	73.8(100)
Sodium borate (Borax)	1.6(10)	14.2(55)
Solubor	4.5(10)	32.0(50)
Copper sulphate	31.6(0)	203.3(100)
Manganese sulphate	105.3(0)	111.2(54)
Ferrous sulphate	15.6	48.6(50)
Sodium molybdate	56.2(0)	115.5(100)

The figures in parentheses are the temperatures (°C) at which the solubilities were determined.